SCIENTIFIC AMUSEMENTS

FOR

YOUNG PEOPLE

PEPPER.

HUMPHRY DAVY'S YOUTHFUL EXPERIMENTS. *Front.*

SCIENTIFIC AMUSEMENTS

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YOUNG PEOPLE;

COMPRISING

CHEMISTRY.
CRYSTALLIZATION.
COLOURED FIRES.
CURIOUS EXPERIMENTS.
OPTICS.
CAMERA OBSCURA.
[illegible]

KALEIDOSCOPE.
MAGIC LANTERN.
ELECTRICITY.
GALVANISM.
MAGNETISM.
[illegible]
[illegible], ETC.

BY

JOHN HENRY PEPPER,
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With above One Hundred Illustrations.

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AEROSTATION.
ARITHMETIC, ETC.

BY

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F.C.S., A. INST. C.E., LATE PROFESSOR OF CHEMISTRY AT THE ROYAL POLYTECHNIC, AUTHOR OF "THE PLAYBOOK OF SCIENCE," "THE PLAYBOOK OF METALS," ETC.

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SCIENTIFIC AMUSEMENTS.

Fig. 1.

INTRODUCTION.

MANY years ago, a little boy, with his face most unpleasantly speckled with a number of small scars (just healing), happened to meet that awful personage the "Family Doctor," who was coming down stairs from a grand medical consultation with mamma and the assembled inmates of the nursery. The grave son of Æsculapius at once and most tenderly inquired (oh! that dreadful physic bill) after the health of the juvenile, with a view, no doubt, to correct the excessive heat of blood which had caused so frightful an eruption on his youthful countenance. And "Pray, sir," asked the doctor, "what is the matter with you?" The boy, half frightened at the distant prospect of bolus and draught, replied, in the usual lucid manner, "Nothing, sir." "Nothing!" said the doctor; "why what an inflammatory state your skin is in; I must send you some cooling medicine immediately, my *dear* boy." "Oh, sir, please sir,

don't; it's phosphorus!!" The doctor forgot his dignity, and stared with amazement; he was clever, but of the very old school; he waited one moment, felt the boy's pulse, and looked hard in his face again as if to count the spots, and at last his pent-up feelings found vent. "Take care, sir! take care, or you'll blow your head off with your chemical pranks; and now tell me how it happened." The youthful philosopher was not long in relating he had read in a book on chemistry, that if phosphorus and chlorate of potash were rubbed together in a mortar, they made a "*bang*," which he had tried accordingly in his bedroom, secretly, with the help of the kitchen mortar; that the *stuff* would not go off at first, and whilst he gathered up all his strength and gave the blow that produced the *stunning* effect, his face, somehow or other, came over the mortar, and all the phosphorus blew up into it; and "a lucky fellow," rejoined the doctor, "you are, to escape the penalty of *injured eyes*;" and so will every one say who reads this account; but the moral of our story is, the *caution* to all would-be *juvenile philosophers* not to attempt experiments they do not thoroughly understand, and especially to avoid those results that merely end in explosions, and try only those combinations of chemical substances which are *pleasing* and *without danger*, such as will now be described in the following popular sketch of the Science of Chemistry.

Fig. 2. The danger of experiments with explosive bodies.

CHEMISTRY.

In the history of nations we read of a very brave and talented people who, under the name of the "Moors," and sometimes called the "Saracens," helped to rescue the rude Romano-German population of Europe from the Gothic brutishness and ignorance into which they had lapsed. The warlike Moors originally came from Arabia, and are, therefore, the descendants of Ishmael; and although, when conquerors, they were (at first) quite as ready to destroy as to create, and, in pursuit of the former evil passion, even burnt the magnificent library of Alexandria; yet, when they had conquered and gained wealth, they cultivated learning of every kind, and became highly civilized; so that, when they ruled Spain, they introduced into Europe the science of astronomy, the principles of numeral notation, algebra, and the noble science of chemistry, which derives its name (according to the Rev. Mr. Palmer, Professor of Arabic) from the word "alchemy," or more properly "al-kemy," *the knowledge of the substance or composition of bodies*, so named from the substantive (kyamon), that is, *the constitution of anything*, derived from the root *kama*.

It is pretended by some that the words chemistry and alchemy are derived from the name of Shem or Chem, the son of Noah, who is said to have been an adept in the art, and to this day there are persons who assert that the Jews still possess the art of making gold, or they could not possess such fabulous wealth. Others say the art was derived from the Egyptians, amongst whom it was founded by Hermes Trismegistus. The Jesuit, Father Martini, in his "Historia Sinica," says it was practised by the Chinese 2500 years before the birth of Christ; but, as he does not produce any proofs or data upon which this statement is founded, his assertion is worth very little or nothing. There can be no doubt that impostors, who deceived the unwary with the pretence of making gold and silver, existed in Rome in the first centuries after the Christian era, and that, when discovered, they were liable to punishment as knaves and swindlers.

At Constantinople, in the fourth century, the art of transmutation was fully believed in, and many Greek ecclesiastics wrote learned treatises thereon; of these and other distant periods the information respecting alchemy must be considered doubtful; but it is certain that in the eighth century

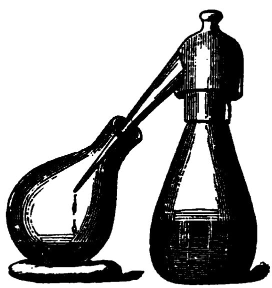

Fig. 3. An alembic, or alambic, employed by the alchemists for the process of distillation and sublimation.

the art reappeared amongst the Arabians. Now, there are many words in common use which are derived (like the word alchemy) from the Arabic language, such as "Al-manack," "Al-koran;" and hence it is not surprising to find chemical words which have the like origin. Thus the word "Al-kali," derived from *kali* a plant, *al-kali* of a plant, representing an important class of chemical bodies having opposite qualities to acids, is clearly of Arabic origin; so again, with the names of apparatus, such as the alembic or alambic. This is compounded of the Arabic particle *al* the, and the Greek word *ambix*, a kind of cup or cover of a pot. It is now used to denote the whole of an apparatus for distilling, as in Fig. 3; but it formerly denoted, according to Bishop Watson, only one part of it—viz., the head, or that part in which the distilled matter was collected.

Astrology preceded astronomy, and alchemy paved the way for the science of chemistry. Much valuable time and money were thrown away by learned but misguided men, who, groping their way in the dark, and not having the advantage of perusing books written by shining lights—such as Sir Humphry Davy or Faraday—stumbled on many valuable truths in their pursuit of the ever-attractive "Philosopher's Stone," which was to turn lead into gold; or, as a magical potation, under the name of the "Elixir of Life," was not only to impart longevity, but continual life, so that the maker of the gold should not lose it in the grim clutch of King Death. The worldly desire to *have* and *enjoy* is well depicted in these dreams of the alchemists, whilst the most intense nonsense is apparent in many of their notions; thus, in a "Discourse on divers Spagyrical [*i.e.* chemical] Experiments and Curiosities, and of the Anatomy of Gold and Silver," by one John French, "Doctor of Physick," and printed as late as 1651, in the time of the "Commonwealth" of Oliver Cromwell, we are gravely told how "*To extract a white milkie substance from the rayes of the moon;*" at the same time, in this discourse there is much that is useful, and we learn that distillation may be conducted by a lamp; and this statement is accompanied with a diagram, of which a copy is given (Fig. 4) where we see the germ—the principle of Palmer's celebrated spring candlestick, in which the candle is maintained at one height by the compression and elasticity of a spring.

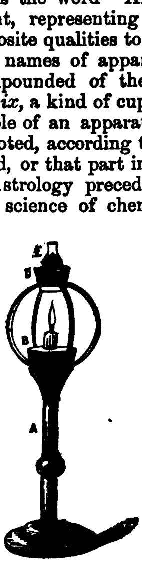

Fig. 4. A signifies the candlestick, which must be hollow and full of *water*.

B. The top of the candlestick, which must be wide, to contain good store of water, *for* to fill up the candlestick as the candle riseth up.

C. The candle, which must be as long as the candlestick.

D. The vessel that contains either water, sand, or ashes for any vessel to be set into.

E. A glass vessel standing in *digestion*.

Grave and honest men continued their studies in alchemy with amazing industry—the clever chemist, not alchemist—Boerhaave, distilled mercury 1009 times in order, as he says, in his paper

addressed to the Royal Society, "to subvert the high pretensions of other alchemists that mercury could never be freed from its original impurity but by being joined to some purer body of the same nature with itself, such as gold or silver," as also to prove "the unchangeableness both of mercury and gold, how often soever they were distilled together."

During the time that the true believers continued their experiments there was another class of men who, with consummate impudence, possessed themselves of a few chemical terms and hard words, and astonished the ignorant with juggling tricks, which passed for true alchemy. They had only to consult the works of clever, perhaps honest alchemists, to learn the magniloquent style of describing experiments. There was Paracelsus, who was undoubtedly a most learned man, and called by Naudé "the zenith and rising sun of all the alchemists;" he indulged in a rampant style of puffing himself. In the year 1526 he was chosen Professor of Physics and Natural Philosophy in the University of Basle, where his lectures attracted vast numbers of students; he treated the physicians of his time with the most absurd vanity and illiberal insolence, telling them "that the very down of his bald pate had more knowledge than all their writers, the buckles of his shoes more learning than Galen and Avicenna, and his beard more experience than all their universities;" he revived the extravagant doctrines of Raymond Lully con-

Fig. 5. The death of *Bombastes* Paracelsus by drinking alcohol, being his alleged *Elixir of Life.*

cerning an universal medicine, and boasted himself to be in possession of secrets able to prolong the present period of human life to that of the Antediluvians: he had, in fact, made the discovery of alcohol, and thought that in it he had found the long-sought elixir of life. Paracelsus determined to put it to the test, and, drinking copiously of his alcohol (with a daring worthy of a better cause), sank dead on the floor of his laboratory—a type, as Cumming says, "of man's effort to save himself—that is, to live for ever!"

Fig. 6. A. Real gold. B. Common iron. The whole, being painted over with a reddish colour, would have the appearance of a rusty nail.

The swindlers and cheats did not propose to themselves such tragic experiments, but studied carefully the art of deceiving fools (of whom, it is said, the human race is chiefly composed) by first awakening the passion of avarice; thus they would invest a little of the precious metal in the construction of a nail half gold and half iron, and meeting with a victim of the required softness, they would then carelessly remove it from their pockets in company with other nails, and, producing a phial of the elixir, would expend the *last drop* in changing the nail into gold; the elixir, of course, being coloured water that could wash off the paint with which the nail was covered.

The *last drop* of elixir being expended, it was of course necessary for the alchemist to prepare *some more*, and presenting the nail as an earnest of his power, he would be at free quarters for many months with his patron, who would incur, at the alchemist's suggestion, unheard-of expenses for chemicals, glasses, furnaces, &c., until tired out with repeated failures, he would send the alchemist (not empty) away, to repeat in some other locality the same impertinent trick on the wisdom of his fellow-creatures. There is nothing that better demonstrates the shrewdness of Queen Elizabeth than her dealings with Dr. Dee. Like our own beloved Sovereign, she was the patron of learned men, and having been presented with a round piece of silver which Dr. Dee pretended he had made of a portion of brass cut out of a warming pan, the said pan being afterwards sent to her majesty that she might convince herself that the piece of silver exactly corresponded with the hole which was cut into the brass; did receive him most favourably, at least so far as words went, and gave orders that he should not be molested in his pursuits of chemistry and philosophy, at the same time, with most sensible queen-craft, intimated that the man who could make silver must be *perfectly independent* of her exchequer.

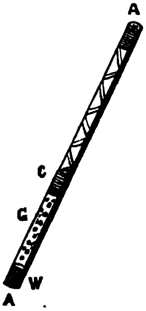

Fig. 7. A. Hollow metal rod, in which W represents the wax, to close one end. G. The grains of gold. C. A cork, to prevent the grains of gold making a noise in the tube.

There were other mendicant rogues who pretended to transmute vulgar lead and copper into royal gold by certain powders, which they projected and always *stirred* into the baser metal,

to the wondering delight and edification of all concerned. In fact, the *stirrer* was the *primum mobile* in this amusing fraud; and after the fashion of the wonderful miracle of producing the omelette in the empty frying-pan, as narrated by all truth-loving chroniclers of Spain and her mendicant monks, these cunning jugglers previously conveyed their atom of gold into the hollow of the *stirrer*, and by the help of a little powdered charcoal, sulphur, and nitre, which made a great deflagration or fizz, when thrown into the red-hot crucible, the eyes of the curious were dazzled, and the conjurors passed themselves off as the possessors of the true philosopher's stone, and rewarded the believers and reproved the incredulous by the production of a modicum of gold.

It were tedious to give the names of all the alchemists who have distracted the peace of mind of others who succeeded them by their insane ravings after the mysterious chemical which was, by multiplication on the largest scale, to produce a mountain of gold from a molehill of *the quintessence;* it is sufficient to know that, so far as our modern chemistry enlightens us, it is impossible to change one element into another. There are certain substances which are called *allatropic*; that is to say, they are capable of assuming one or more physical states, and putting on such disguises, that even the best devised masqueradedress cannot approach them in the perfection of concealment.

Fig. 8. Alchemist using his hollow rod.

Thus charcoal, which possesses almost the property of ubiquity, is to be found as the very cornerstone in the fabric of the fairest faces of Eve's daughters. It lurks in the sweetened cup of tea, and a quarter of a pound of nice white lump sugar put into a breakfast-cup with the smallest possible dash of boiling-water, and then the addition of plenty of oil of vitriol, is a truly wonderful spectacle, and more instructive than much reading; to see the white sugar turn black, then boil spontaneously, and now rising out of the cup in solemn black, it heaves and throbs as the oil of vitriol continues its work in the lower part of the cup, emitting volumes of steam and reminding one of some of those remarkable upheavings of the earth which geologists delight to paint and talk about, till the acid has spent its fury; the elements forming water in the sugar have been attracted,

Fig. 9. Breakfast cup containing a quarter of a pound of lump sugar, upon which a little boiling water has been poured, and then plenty of sulphuric acid.

and are now united to the oil of vitriol (scientifically called sulphuric acid), a divorce has taken place between the water and the charcoal, which latter now tumbles over the sides of the cup.

In describing this experiment the other state of charcoal (the allatropic condition) must not be forgotten. The breakfast-cup is full of—no! not diamonds!—it only contains a porous sort of black charcoal; and yet, in Nature's hand, this common black matter is moulded into the costly diamond, and, glancing from the ring on the finger to the solid contents of the cup, it is difficult to trace out any analogy; but this is the point of the argument, and is the nearest approach to the alchemical fantasy of our forefathers. A substance may take two or three forms, as already described, but it is impossible, so far as experience teaches us, to change one *element* into another. We may have charcoal—as coke—the diamond—plumbago—anthracite, a smokeless coal—but we cannot change it, or lead, or copper into gold, unless we adopt the time-honoured and most successful mode of transmutation, and become coal, lead, or diamond merchants.

Speaking of elements, brings us to the consideration of chemistry as a modern science. Just eighty-seven years ago Dr. Priestley began his famous experiments with the preparation and examination of various gaseous bodies, one important result of which was the discovery of "oxygen gas," the foundation of the present classified and embodied series of facts that record the labours of so many talented men. Thus oxygen deservedly stands at the head of the list of the elements which form every animate and inanimate thing within, upon, or about the world. There is nothing more encouraging to a beginner in chemistry, such as the youthful philosopher who expends his shillings and sixpences in chemicals and apparatus, who disdains to play out his half-holidays, and, enraptured with the wonders of which he is the magician, is better pleased experimenting in the secluded garret-room than in the noisy playground—there is nothing more satisfactory than the statement that the highest mountain and the lowest valley, the most beautiful summer-cloud or the grandest cataract of water, the ugliest reptile or the most graceful form, the noblest palace erected by the hand of man, with its pictures, statuary, paintings, carpets, furniture, silks, satins, velvets, its costly jewels, diamonds, pearls, rubies, and sapphires, or the poorer hovel, with its shivering tenants in rags, can each and all be referred in composition to some sixty-two or -three elements, which are easily classified, viz.:—

Three permanent gases—oxygen, nitrogen, hydrogen.

Four elements having many similar characteristics—chlorine, bromine, iodine, fluorine.

Five solids which do not possess the usual metallic properties—carbon, boron, selenium, sulphur, phosphorus.

Fifty metals, only one of which is a liquid—viz., quicksilver or mercury—all the others being solid.*

In this list there is the alpha, beta, gamma, delta of chemistry, puzzled out by the laborious work of some of the most talented and

* For more extended information on these elements, the reader is referred to the "Playbook of Science," and the "Playbook of Metals." (Routledge, Warne and Co.)

gifted of men, and, once grasped, this chemical alphabet is the stepping-stone to compound words of one or more syllables, or containing one or more elements. Thus oxygen and hydrogen combined spell *water;* charcoal, oxygen, and calcium, chemically united, spell *the marble arch;* carbonate of lime, sulphur, oxygen, aluminium, potassium, spell *alum.* The word *spell* is pressed into the service, and is intended, of course, to be a synonym for the verb to form or produce; at all events, having been once used in this way to help an analogy, we may lay it on one side, and now begin to describe some of these experimental lessons, commencing with

THE ATMOSPHERE.

NITROGEN is the principal constituent of the air of the atmosphere which surrounds our globe, extending to a height of about forty-five miles above it, and playing a most important part in the economy of nature, inorganic as well as organic.

This atmospheric air consists of nearly four-fifths of nitrogen, and rather more than one-fifth of oxygen, about seventy-nine of the former to twenty-one of the latter, and generally contains also a variable proportion of the vapour of water, and a very small quantity of carbonic acid gas, scarcely amounting to 1 part in 1000. Its constituent parts are so easily separated, that it appears to be rather an intimate mixture than a chemical compound, though the mixture is so complete that chemists have not been able to ascertain any difference in the composition of air taken from all parts of the world, and from different heights, up to the highest point which has to this time been attained.

This atmosphere presses on the surface of the globe and every being on it, with a force of about fifteen pounds to every square inch of surface, but as it presses equally in all directions, upwards as well as downwards, its weight cannot be perceived unless the pressure be removed from one surface by some artificial means.

EXPERIMENTS.

1. Place a cylinder of strong glass, open at both ends, on the plate of the air-pump, and put your hand on the other end, and you will of course be able to remove it at pleasure. Now exhaust the air from the interior of the cylinder, and at each stroke of the pump you will feel your hand pressed tighter and tighter on the cylinder, until you will not be able to remove it; as soon as the air is again admitted to the interior of the cylinder, the pressure within will be restored, and the hand again be at liberty.

2. Tie a piece of moistened bladder very firmly over one end of a similar glass cylinder, and place the open end on the plate of the pump. As soon as you begin to exhaust the air from the interior, the bladder, which was previously quite horizontal, will begin to bulge inwards, the concavity increasing as the exhaustion proceeds, until the bladder, no longer able to bear the weight of the superincumbent air, breaks with a loud report.

3. The elasticity of air, or indeed of any gaseous body, may be shown by introducing under the air-pump receiver a bladder containing a very small quantity of air, its mouth being closely tied. As you exhaust the air from the receiver, that portion contained in the bladder being no longer pressed upon by the atmosphere, will gradually expand, distending the bladder until it appears nearly full; on re-admitting the air into the receiver, the bladder will at once shrink to its former dimensions.

A shrivelled apple placed under the same conditions, will appear plump when the air is removed from the receiver, and resume its former appearance on the re-admission of the air.

4. There is a very pretty apparatus made for the purpose of showing the pressure of the atmosphere, consisting of a hollow globe of brass, about three inches in diameter, divided into two equal parts, which fit very accurately together; it is furnished with two handles, one of them screwed into a hollow stem, communicating with the interior of the globe, and fitting on to the air-pump; the other is attached to a short stem on the opposite side of the globe. In the natural state, the globe may easily be separated into its two hemispheres by one person pulling the handles; but after the air has been exhausted from the interior, it requires two very strong men to separate the parts, and they will often fail. By turning the stopcock, and re-admitting the air into the interior of the globe, it will come asunder as easily as at first.

THE BAROMETER.

We are indebted to the weight of the atmosphere for the power we possess of raising water by the common pump, for the piston of the pump withdrawing the air from the interior of the pipe, which terminates in water, the pressure of the atmosphere forces the water up the pipe to supply the place of the air withdrawn. It was soon found, however, that when the column of water in the pipe was more than thirty feet high, the pump became useless, for the water refused to rise higher. Why? It was found that a column of water about thirty feet high, exerted a pressure equal to the weight of the atmosphere, thus establishing an equilibrium between the water in the pipe and the atmospheric pressure.

Fig. 10.

This is the principle on which the barometer, or *measurer of weight*, as its name imports, is constructed. The metal Mercury is about twelve times heavier than water, consequently, if a column of water thirty *feet* high balances the pressure of the atmosphere, a column of mercury thirty *inches* high ought to do so also, and this is in fact the case. If you take a glass tube nearly three feet long, and closed at one end, fill it with mer-

cury, then placing your finger on the open end, invert the tube into a basin or saucer containing some of the same metal; upon removing your finger (which must be done carefully, while the mouth of the tube is completely covered by the mercury), it will be seen that the fluid will fall a few inches, leaving the upper part of the tube empty. Such a tube with a graduated scale attached, is in truth a barometer, and as the weight of the atmosphere increases or decreases, so the mercury rises or falls in the tube. This instrument is of the greatest value to the seaman, for a sudden fall of the barometer will often give notice of an impending storm, when all is fine and calm, and thus enable the mariner to make the preparations necessary to meet the danger.

This instrument was discovered by an Italian philosopher, named Torricelli, and from him the vacuum formed in the upper end of the tube above the surface of the mercury, has been called the Torricellian vacuum. It is by far the most perfect vacuum that can be obtained, containing necessarily nothing but a minute quantity of the vapour of mercury.

EXPERIMENT.

Pass a little ether through the mercury in the tube, and as soon as it reaches the empty space it will boil violently, depressing the mercury until the pressure of its own vapour is sufficient to prevent its ebullition. If you now cool the upper part of the tube, so as to condense the vapour, the pressure being thus removed, the ether will again begin to boil, and so alternately, as often as you please. In order to show this fact with effect, the bore of the tube should not be less than half an inch in diameter.

ATMOSPHERIC AIR.

Atmospheric air contains, beside the oxygen and nitrogen, its principal constituents, a small proportion of carbonic acid gas, as has been mentioned, and this may be shown by filling a tube about half full of lime-water, and shaking it with the air contained in the other half, when it will become slightly turbid from the insoluble carbonate of lime formed.

When we consider that every living animal is constantly consuming oxygen, and replacing it by carbonic acid gas, and that all burning bodies, fires in our dwellings, furnaces, artificial lights of all kinds, act in the same way in abstracting the oxygen from the air, and replacing it by immense quantities of carbonic acid gas, which is a poison to all animals who breathe, or attempt to breathe it, we must wonder what becomes of this irrespirable gas, as it is found to exist in the air in quantities so minute, and by what means the oxygen is restored, and the air again made fit for respiration. This is effected by one of those laws which the wisdom of the Creator has impressed upon matter, by which one part of creation as it were balances another, and all proceeds in an endless circle of change. This carbonic acid, which is so poisonous to animal life, is the food of the vegetable world, plants having the power of taking up the carbonic

acid into their pores; converting the carbon into their own substance, and rejecting the oxygen, which is again respired by animals, &c. In the same way, all animal refuse is the food of vegetables, and is used under the name of manures.

The atmosphere contains also a variable quantity of vapour of water, invisible so long as it is in the state of vapour, but it may be rendered obvious by bringing any very cold body into warm air, when the vapour will condense on the cold body in the form of small drops of water. A tumbler of fresh-pumped water brought into a crowded room, is almost immediately covered with moisture, and it may also be seen on bottles of wine which have been put into ice before coming to table. Fogs are occasioned by the condensation of vapour, produced by mixing a current of warm air with a colder air. The banks of Newfoundland are notorious for dense fogs, occasioned by the warm air brought from the south by the Great Gulf Stream mixing with the cold air from the Arctic regions, and thus precipitating the vapour in a visible form, rendering everything but itself *in*visible. The famous London fogs depend upon the same precipitation of the vapour of water, with the addition of the smoke from the numerous sea-coal fires, which give it that interesting yellow tinge for which it is so remarkable.

Aqueous vapour being lighter and more transparent than air, permits objects to be seen more distinctly in proportion to its quantity; hence, when distant hills appear nearer, and objects upon them more distinct than usual, rain may be expected, the air being fully charged with vapour ready to be deposited on the slightest cause.

THE VARIOUS MODES OF PREPARING OXYGEN GAS.

Procure an old gun-barrel, and plug up the touch-hole with wire, or, if a larger quantity of oxygen is required, obtain an empty iron quicksilver bottle, which may be purchased at Mr. Gale's, ironmonger, Oxford-street, for some three or four shillings. In the first place, fit into the gun-barrel a cork with a pewter tube, or stretch a piece of vulcanized india-rubber tube over the end of the gun-barrel, having previously poured in some black oxide of manganese, in grain, not powder, as the latter contains water, which, expanding into steam, has a tendency to blow out the powdered manganese, causing it to clog the pewter tube or vulcanized india-rubber tubing. If the touch-hole end be now placed between the bars on an ordinary fire, and the tube conveyed an inch or so beneath the surface of some water in a pail or foot tub, bubbles of gas will soon escape, which can be collected in a bottle previously filled with water and held over the end of the pipe; the gas ascends into the bottle, gradually displacing the water, and, when filled, the bottle is corked, or stoppered, under water, and removed for use.

If the large mercury bottle is used, an iron pipe is screwed into the orifice, from which the plug is removed, and when the pipe is fixed, the bottle is filled with grain manganese and placed in a proper

furnace, whilst the gas can be conveyed to a pneumatic trough by means of vulcanized india-rubber tubing, which is remarkably useful for all experiments connected with the gases.

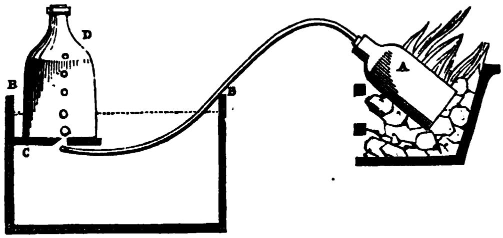

Fig. 11. A, the iron bottle containing the black oxide of manganese, with pipe passing to the pneumatic trough, B B, in which is fixed a shelf, C, perforated with a hole, under which the end of the pipe is adjusted, and the gas passes into the gas jar, D.

ANOTHER MODE OF MAKING OXYGEN GAS.

Obtain a Florence oil flask, and having cleaned out the oil by means of some bits of soap and boiling water, and thoroughly washing the flask, let the vessel dry, and then take away the wicker work, which need not be wasted, as it can be coiled round and bound, and answers admirably for a stand to support the flask upright. Into the flask place a mixture of two ounces of powdered chlorate of potash and one ounce of powdered black oxide of manganese, both of which should be dry and well mixed before they are placed in the flask; then fit a cork and pewter tube. The cork can be easily bored, either with a *rat-tail* file, or, what is still better, a *cork-borer*, which can be purchased at any of the chemical apparatus shops. Now place the flask and

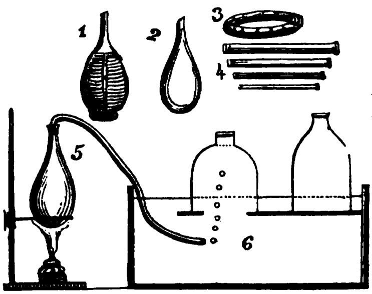

Fig. 12. 1. Florence oil flask with wickerwork.
2. Ditto cleaned and dried.
3. The wicker converted into a pad to rest the flask on.
4. Cork borers fitting into each other, and of all sizes.
5. Flask fitted with cork and bent tube, and containing the chlorate of potash and black oxide of manganese, with spirit lamp. The pewter pipe leads to No. 6.
6. Pneumatic trough. The gas jar standing on the shelf, and receiving the bubbles of gas from No. 5.
N.B. With the above arrangement nearly all the most interesting gases may be prepared.

bent-tube on a ring-stand, and apply the heat of a spirit-lamp, when torrents of gas will escape. The oxygen may be collected in gas jars or bottles over the pneumatic trough, and pictures of all the apparatus used are given here, to assist the manipulation of the youthful chemist, who will of course be most desirous to begin by making oxygen gas.

EXPERIMENTS WITH OXYGEN GAS.

If a lighted taper is blown out so as to leave a part of the *snuff* (so-called, *i.e.* the wick) in a state of ignition, and then plunged into oxygen gas, the taper relights with a slight pop or noise, being a good example of the power of oxygen to *support combustion.*

CURIOUS COLOURED LIGHT OBTAINED BY BURNING SULPHUR IN OXYGEN.

Into a deflagrating spoon, which is a little cup made of brass or copper screwed on to the end of a copper or iron wire, place a little sulphur; when set on fire, and plunged into oxygen, it emits a most remarkable coloured light. After the combustion is over, some amusing experiments can be made with the product.

TO BLEACH A RED ROSE AND OTHER FLOWERS.

If a red rose be placed inside the jar where the sulphur has been burnt, the colour is discharged, and the rose rendered nearly white.

Many variegated dahlias, blue heartsease, or a bunch of blue violets, have their colours curiously modified, if not bleached, by the acid produced, which is called sulphurous acid, and is most largely employed for bleaching straw hats and bonnets. The same acid is exceedingly valuable as a disinfectant, and also for arresting fermentation. Many casks of *home-made wine* become *home-made vinegar* in consequence of the rapidity of the fermentation in warm weather; and the fumes of sulphur, obtained either by burning that substance in air or oxygen, have the remarkable power of stopping the too-rapid conversion of sugar into alcohol. The sulphurous acid described is one of the most ancient bleaching agents, and it is even mentioned by Pliny as used for whitening woollen fleeces.

TO OBTAIN A WHITE SOLID FROM THE WATER IN WHICH THE GAS-JAR CONTAINING THE SULPHUROUS ACID STANDS.

After trying the bleaching experiments explained, let the gas-jar and the remaining fumes stand for some little time in a dish with water containing a little nitric acid, when the acid and some sulphuric acid will gradually fall into and mix with the water, which should be pure and distilled. If a piece of paper coloured blue with tincture of litmus be dipped into the water, it changes red, demonstrating the presence of an acid body; and, on the addition of a solution of nitrate of baryta, a white precipitate falls, called sulphate of baryta, or *heavy white.* This is a pigment largely used for enamelled

papers, and is also sometimes employed to adulterate white lead. Experiments can always be made, instructive as well as entertaining, and the production of the *heavy white* is a good example of chemical affinity, as well as of the indestructibility of matter, for it now contains the greater part of the sulphur originally burnt in the oxygen gas—sulphate of baryta consisting of 16 parts sulphur, 32 parts oxygen, and 68½ parts of the metal barium.

TO MAKE TEST PAPERS.

Test papers are exceedingly valuable to the experimental chemist for the purpose of detecting the presence of acids and alkalies, and they may be prepared in the most simple manner. Take an ounce of litmus and place it in a ten-ounce bottle, pour upon it a mixture of five ounces of alcohol (methylated spirit will do very well) and five ounces of water; continually shake the ingredients during several days, when a deep blue tincture will be obtained, which may be poured off clear into another bottle, or filtered through blotting-paper. To use the *tincture* of litmus (for all solutions of vegetable substances in alcohol are generally called tinctures, especially when employed in medicine), pour a little into a soup-plate, and then take some strips of blotting-paper, pass them through the tincture, when they will absorb sufficient to colour the paper a lovely blue, which is now to be hung up, and when dry placed in a well-corked or stoppered wide-mouthed bottle in a dark place. The paper is now called litmus paper, and is an exceedingly delicate test for acid bodies soluble in water.

TURMERIC PAPER.

This test is used to detect alkalies, and, in contact with a solution of potash, soda, or ammonia, changes to a reddish-brown; it is prepared in precisely the same manner as the litmus paper, by using one ounce of powdered turmeric root to five ounces spirit and five ounces water.

ANOTHER DELICATE TEST FOR ALKALIES.

Take some litmus paper and pass it through very weak vinegar, and hang it up to dry. The paper is now red; but, in the presence of an alkali, it immediately changes to a blue, as may be noticed in trying some other amusing experiments with oxygen gas.

INTENSE HEAT AND LIGHT PRODUCED BY BURNING PHOSPHORUS IN OXYGEN.

If this experiment is tried with the precautions mentioned, the gas-jar may be usually saved; but, if carelessly performed, the heat produced is so great that it generally cracks the glass. Take a moderate-sized piece of phosphorus and dry thoroughly by pressing it gently in blotting-paper; place this in a deflagrating spoon, and, having previously removed the stopper of the gas-jar containing the oxygen, place the spoon and its contents in the neck of the jar, and

then ignite the phosphorus by touching it with a hot wire. Now place the spoon in the centre of the jar, when a dazzling bright light is obtained. This experiment is made still more amusing by first showing some flowers in pots and coloured silks by a monochromatic light, and afterwards lighting up the phosphorus, when all the colours are shown with great brilliancy. In this case the gas-jar should be screened from the eyes of the spectators, so that they may be able to appreciate the changes of colour in the articles displayed by the two lights.

A MONOCHROMATIC LIGHT.

Into a pint-bottle of methylated spirit place two ounces of common salt, which must be constantly shaken; after agitation, pour some on a cloth or some cotton-wool tied round a stick and placed in the nozzle of a common candlestick. If flowers or coloured shawls are exhibited by the light obtained from the burning spirit containing the salt, they present a most dreary and monotonous appearance, and the contrast is very marked when the jar of oxygen is produced and the phosphorus burnt—the colours appear to be restored as if by magic. Of course these experiments must be prepared in a darkened room—a room with shutters is very convenient for these experiments.

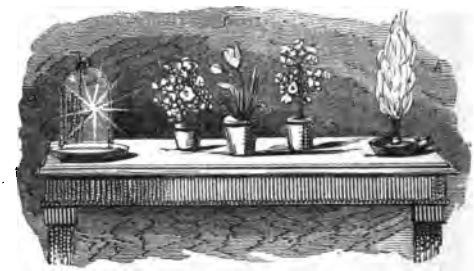

Fig. 13. Table set out in a darkened room.
A. The candlestick and cotton saturated with spirit and salt, burning and producing a yellow light.
B. The phosphorus in oxygen.
F. Flowers of various colours in centre of table.

AN ACID OBTAINED BY BURNING PHOSPHORUS IN OXYGEN.

If the phosphorus is burnt in a jar containing dry oxygen gas, the phosphoric acid deposits in white flakes which, if mixed rapidly with lime and a little water, constitute a useful material for stopping teeth, as the lime and phosphoric acid unite and form phosphate of lime; this substance is perfectly harmless, and unlike the dangerous mercurial amalgams placed in hollow teeth, cannot injure the health of persons using it. If the jar of oxygen stands

in a plate containing water, the white flakes of phosphoric acid rapidly dissolve, and when tested by the litmus paper, betray the presence of the acid by the change of the blue to red. This experiment contrasts curiously with the next.

AN ALKALI PRODUCED BY BURNING A METAL IN OXYGEN, AND THE CHAMELEON EXPERIMENT.

Potassium is lighter than water, and when placed in a spoon and heated by a spirit-lamp, and then plunged into a jar of oxygen, it glows with an intense and sudden heat. If the product contained in the spoon is now dissolved in water, the solution changes the colour of the turmeric from a yellow to a reddish brown, showing that oxygen can not only produce an acid but an alkali; and a very interesting result is obtained by taking the litmus paper changed to red from the phosphoric acid, and restoring the blue by dipping it into the solution from the potassium, or by taking the turmeric paper, already changed to a reddish-brown by the alkali, and bringing back the bright yellow by placing it into the phosphoric-acid solution. This experiment, which is quite chameleon in its character, is very easily performed, and furnishes a striking example of the difference between acids and alkalies.

COMBUSTION OF STEEL SPRING IN OXYGEN.

Take a bit of watch-spring, and *soften* the *end* by means of the flame of a spirit-lamp. When cold, twist round it a piece of waxed thread or waxed taper. If this is set on fire, and introduced into a jar of oxygen, the steel spring burns with great intensity, throwing out sparks in every direction; and as these are extremely hot, they strike against and melt themselves into the body of the glass; other portions fall into the water below, and frequently pass through the stratum of water, melting the glaze and adhering firmly to it. In this experiment the result is neither acid nor alkaline, but a mixture of the oxides of iron, a neutral compound being formed; and it is very curious here to mark the elasticity, hardness, and toughness of the steel as compared with the product of combustion, which is so brittle that it may be crushed by the fingers in the palm of the hand.

FIRE FROM WATER, OR THE MODERN GREEK FIRE.

Potassium will burn very readily in oxygen gas, the combustion being retarded chiefly from the formation of a crust of oxide or potash covering the metal. This does not occur if potassium is thrown on water: the metal oxidizes rapidly, and so much heat is generated during the change, that the hydrogen escaping around the ignited ball takes fire, whilst the potash formed on the surface is rapidly cleared off, and the whole mass being converted into potash, is at the last a red-hot ball of that substance; and being no longer able to maintain its high temperature, comes in contact with the water, and bursts with a sharp crack; and for that

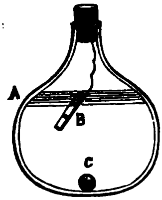

Fig. 14. A. The globe full of naphtha or ether.
B. Slender tube tied to a bit of thread attached to the cork, containing the potassium.
C. The bullet, to ensure the fracture of the glass.

reason, the vessel in which potassium is burnt must not be approached at the last stage of the combustion too closely, as the particles from the red-hot ball of potash would cause intense agony, if they happened to enter the eye.

Advantage is taken of this property in the popular experiment called the "Modern Greek Fire." Globes of glass are filled with ether or naphtha, and a thin glass tube placed inside, containing some small pellets of the metal potassium. If a bullet or a marble is placed in the glass globe, and it is dashed on the surface of the water, the globe, with the slender tube containing the potassium, breaks, the contents are discharged on the water upon which the ether and potassium float, and as the latter takes fire instantaneously, it communicates to the ether or naphtha, and a perfect sheet of fire covers the tank, pond, or lake in which the experiment is performed.

FIRE FROM ICE.

Make a hole in a thick piece of ice, dry it out with some cotton, and place into the hole a bit of potassium, when the metal immediately takes fire, and sometimes is discharged from the hole with great violence, especially if the potassium has been held some time in the fingers and become warm. Care must always be taken not to lean over the ice or water during experiments with potassium, and it should be remembered that it very nearly always explodes when held in the fingers, or warmed before use.

THE ANALYSIS OF AIR.

ONE of the most pleasing and simple experiments is that of analysing air, or separating it into its constituent parts: thus, if a lighted taper be placed in a bottle, it burns at first with its ordinary brilliancy; in a short time, however, the flame diminishes and the work of combustion is brought to an end. It might be thought that the carbon of the taper had removed all the oxygen and converted it into carbonic acid; and to prove that this is not the case, a little burning sulphur, in a spoon, is now introduced, which is not extinguished till some time has elapsed. After this burning phosphorus may be placed into the same bottle, and when the latter substance has ceased burning, no other combustible will continue to burn, as the oxygen is wholly removed, and nitrogen with the white smoke of the phosphoric acid alone remain; the latter soon dissolves away in the presence of a little water, leaving the nitrogen behind.

Nitrogen or azote instantly extinguishes a lighted taper, and is lighter than oxygen, as may be proved by the next experiment.

A LIGHT GAS WILL FLOAT ON A HEAVY GAS LIKE ALCOHOL UPON WATER.

If alcohol, coloured blue with litmus, be placed into a phial, some water may be introduced beneath it by means of a tube, and the former floats on the latter. The same principle may be displayed with the gases; thus, if a jar containing oxygen is inverted, and placed with the mouth upwards, and covered with a glass plate, and another jar, containing nitrogen gas (with a similar glass plate), in the upright position, be placed upon it, the two glass plates can be withdrawn; and a lighted taper being introduced, is first extinguished in the top gas jar, containing the nitrogen, whilst it is immediately relighted on being thrust into the lower jar, containing the oxygen.

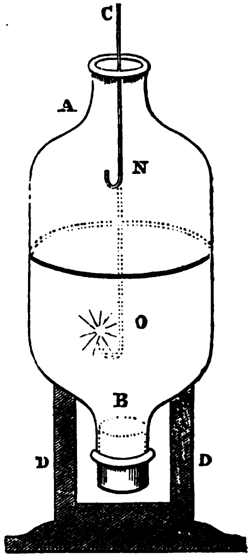

Fig. 15. A, gas jar, containing nitrogen; N, standing on B, another jar full of oxygen, O. The taper C is extinguished at N, and re-lighted at O. D D stand, supporting the jars.

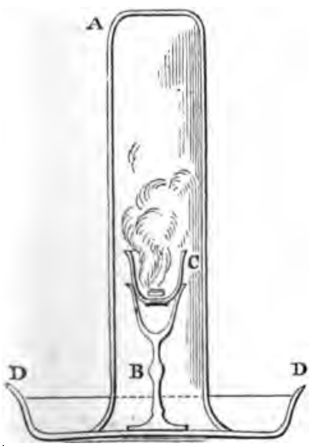

Fig. 16. A. The gas jar, containing atmospheric air.
C. The cup containing the phosphorus.
B. The wine-glass supporting it.
D D. The plate or dish containing water, in which the whole stands.

TO PREPARE NITROGEN.

Into a little porcelain cup, supported on a small wine-glass or other convenient stand placed in a dish with some water, put a piece of phosphorus; set this on fire and invert a jar of air over it, and as the water rises in the jar, pour more into the dish; or, if the stand, &c., be placed on the shelf of the pneumatic trough, the water will absorb the phosphoric acid and rise in the jar in consequence of the removal of one-fifth of the volume—viz., oxygen gas. After

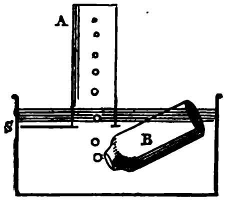

Fig. 17. Gas jar, A, on the shelf, S, of the pneumatic trough, full of water, and mode of passing gas into it from bottle, B.

the white smoke has disappeared, the residual gas is nitrogen.

TO MAKE ATMOSPHERIC AIR.

Take four measures of nitrogen and pass them into a tall jar, or, what is better, graduate or divide a long jar into five equal parts, and fill four of the parts with nitrogen gas, which extinguishes flame; then pass in some oxygen gas, to fill up the remaining one fifth in the graduated long glass; finally, slide a glass plate over the orifice of the jar, and agitate the vessel so as to mix the two gases. A lighted taper introduced into this mixture burns precisely as it would do in common air, and the experiment is very instructive, and shows the synthesis of the chief constituents of common air.

HEAT, OR CALORIC.

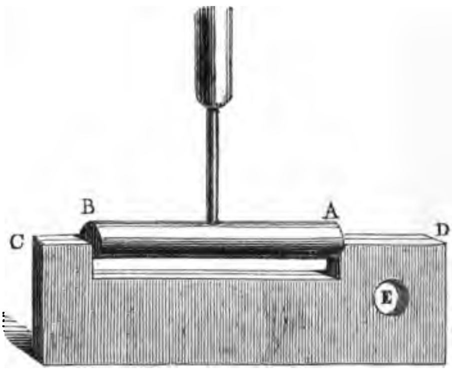

Fig. 18. A B, cylinder of brass. C D, iron gauge, admitting A B longitudinally, and also in the hole E when cold, but excluding A B when the latter is heated and expanded.

THE chief agent in causing the repulsion or separation of the particles of bodies from each other is heat, or more correctly *caloric*, by which is understood the unknown *cause* of the effect called heat. Philosophers are not agreed upon the nature of this wonderful agent: It pervades all nature, is the cause of nearly all the changes that take place, whether in organic or inorganic matter, and has great influence in the meteorological phenomena which we observe in the

atmosphere that surrounds our planet. It appears to be intimately connected with light, electricity, and magnetism, subjects which the genius of Faraday and others is investigating, and by their discoveries bringing us nearer to the knowledge of the real nature of these most wonderful forces.

Caloric, then, exists in all bodies, and has a constant tendency to equalize itself, as far at least as its outward manifestation, called temperature, is concerned; for if a *hot* body be brought near colder ones, it will give up heat to them, until by its loss and their gain they all become of the same temperature; and this proceeds more or less rapidly, according as the original difference of temperature was greater or less. Some other circumstances also influence this equalization. The converse will take place on introducing a cold body among warmer ones, when heat will be abstracted from all the bodies within reach of its influence, until it has absorbed sufficient caloric to bring its own temperature to an equality with theirs. This is the true explanation of the apparent production of *cold.* When, for instance, an iceberg comes across a ship's course, it appears to *give out* cold, whereas, it has abstracted the heat from the air and sea in its neighbourhood, and they in turn act upon the ship and everything in it, until one common temperature is produced in all the neighbouring bodies.

It does not follow that the bodies thus equalized in temperature contain equal quantities of caloric; far from it. Each body requires a particular quantity of caloric to raise its temperature through a certain number of degrees; and such quantity is called its *specific* caloric. A pound of water, for instance, will take just twice as much caloric as a pound of olive oil, to raise its temperature through the same number of degrees; the *specific* caloric of water is therefore double that of oil. Mix any quantity of oil at 60° of temperature with an equal weight of water at 90°, and you will find the temperature of the mixture to be nearly 80°, instead of only 74° or 75°, showing that while the water has lost only 10° of caloric, the mixture has risen 20°. If the oil be at 90°, and the water at 60°, the resulting temperature will be only 70°, or thereabouts, instead of 75°, the mean; thus, here the hot oil has lost 20°, while the mixture has risen only 10°; the water, then, contains at the same temperature *twice* as much caloric as the oil; its specific caloric is *double* that of the oil. This mean temperature does result when equal weights of the *same* body at different temperatures are mixed together.

The sensations called heat and cold are by no means accurate measures of the real temperature of any substances, for many causes influence these sensations, some belonging to the substances themselves, others to the state of our organs at the time. Every one has remarked that metals in a warm room feel warmer, and in a cold room colder than wooden articles, and these again than woollen or cotton articles of dress or furniture; this arises from metals being what is termed better *conductors* of heat than wood, and this better than wool, &c., that is, they give out or absorb caloric more rapidly than these last. Some philosophers, wishing to ascertain how much

heat the human body could endure, had a room heated with stoves, every crevice being carefully stopped, until the temperature rose so high that a beefsteak placed on the table was sufficiently cooked to be eaten. They were dressed in flannel, and could with impunity touch the carpets, curtains, &c., in the room; but the iron handles, fire-irons, and all metallic substances, burnt their fingers; and one who wore silver spectacles was obliged to remove them to save his nose. The fallacy of our sensations may be easily shown by taking two basins, placing in one some water at 100°, in another some water at as low a temperature as can easily be procured—hold the right hand in one, the left in the other, for a few minutes, and then mix them, and place both hands in the mixture; it will feel quite *cold* to the hand that had been in the hotter water, and *hot* to the other.

In order to arrive at a correct estimate of the temperature of bodies, instruments are made use of called thermometers, or measurers of heat, which show increase or diminution of temperature by the rising or falling of a column of some fluid in a tube of glass, one end of which is expanded into a bulb, and the other hermetically sealed. This effect is produced by the expansion or swelling of the fluid as caloric is added to, and its contraction when caloric is abstracted from it. Coloured spirits of wine, or quicksilver, are the most usual thermometric fluids, and the tube containing them is fixed to a wooden or metallic frame, on which certain divisions are marked, called degrees.

That in general use in England is called Fahrenheit's, from the name of the person who first introduced that particular scale. In this thermometer, the point at which the mercury in the tube stands when plunged into melting ice, is marked 32°, and the distance between that point, and the point to which the mercury rises in boiling water, is divided into 180 equal parts, called degrees; so that water is said to boil at $212° = 180° + 32°$ There are two other scales of temperature used in different parts of the world, but it is not worth while to notice them here.

Not only do different bodies at the same degree of temperature contain very different quantities of caloric, but this also is the case with the same body in different forms. Ice, water, and steam, are three forms of the same body, but ice at 32° contains much less caloric than water at the same temperature, and water at 212° contains much less caloric than steam (or water in a state of vapour) at that temperature.

Place in a jar any given quantity of snow, or small pieces of ice, at 32°, and in another the same weight of water at 32°, pour on each an equal weight of water at 172°, and you will find that in the first case the ice will be melted, but the temperature will remain at 32° or thereabouts, while the temperature of the water in the other vessel will have risen to 100° or thereabouts, being as near as possible the half of the excess of the temperature of the hot water, 140° over that of the cold, namely 70° added to 32°, the original temperature. Now, what has become of the heat which was added to the ice, and is apparently lost?—it is *absorbed* by the ice in its

passage to the fluid state; so that water may be said to be a compound of ice and caloric.

Again, take 10 ounces of water at about 50°, and add 1 oz. of water at 212°, and the temperature of the mixture will be about 66°; then condense some steam at 212°, into another 10 oz. of water until it has become 11 oz., and you will find the temperature will be nearly 212°. Why does the ounce of steam at 212° raise the temperature of the water so much higher than the ounce of water at the same temperature? Obviously because it contains hidden in its substance a vast quantity of caloric, not to be detected by the thermometer; in fact, that steam is a compound of *water* and caloric, as water is a compound of *ice* and caloric; and this caloric which exists, more or less, in all bodies without producing any obvious effect, is called *latent* caloric, from the Latin verb *lateo*, to lie hid. The quantity of caloric thus absorbed as it were by various bodies, differs for each body, and for the same body in different forms, as mentioned above.

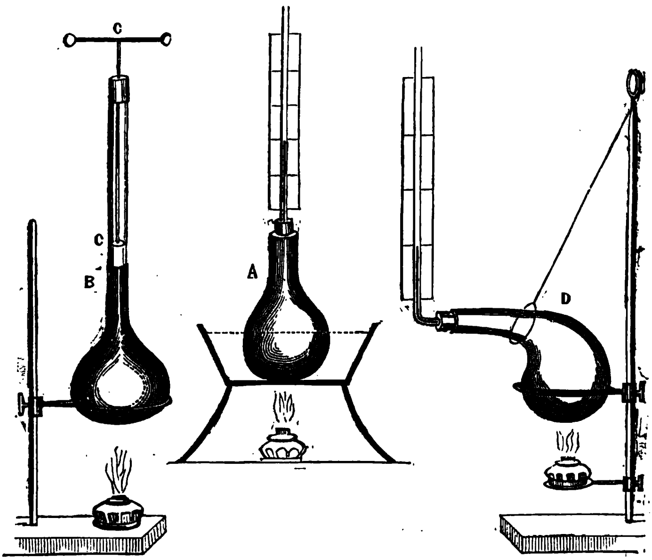

Fig. 19. Expansion of liquids is shown at A by the coloured water rising in the tube from the flask, which is quite full of liquid, and heated by boiling water. B. The expansion of the water heated by the spirit-lamp is shown by the rising of the piston and rod C C. D represents a retort filled up like A to show the expansion of a liquid by heat.

EXPANSION.

As a general rule, all bodies, whether solid, liquid, or gaseous, are expanded by caloric. This may be shown by experiments in each form of matter.

Have a small iron rod made, which when cold just passes through a hole in a plate of metal; heat it, and it will no longer pass; after a time the rod will return to its former temperature, and then will go through the hole as before. The rod increases in length as well as width; if you have a gauge divided into $\frac{1}{100}$ of an inch, and place the rod in it when cold, noting its position, on heating, it will extend to a greater length in the gauge, returning to its former place when cool. (See Fig. 18, p. 20.)

The effect of caloric in causing fluids to expand is actually employed as a measure of quantity in the thermometer, the rise of the fluid in the tube when heated depending on the increased bulk of the fluid occasioned by the addition of caloric. The same fact is to be noticed every day when the cook fills the kettle, and places it on the fire. As the water becomes warmer it expands, that is, takes up more room than it did before, and the water escapes by slow degrees, increasing as the heat increases, up to the point of boiling, when a sudden commotion takes place from a condensation of a portion of the water into steam.

But it is in the form of vapour or gas (which, by the bye, is not the same thing*) that the expansive force of caloric is most obvious. The gigantic powers of the steam-engine depend entirely on the tendency of vapour to expand on the addition of caloric; and this force of expansion appears to have no limit; boilers made of iron plates an inch or even more in thickness, and the buildings or ships containing them, having been torn to pieces and scattered in all directions by the expansive power of steam. Take a bladder, and fill it about half full of air, and tie the neck securely; upon holding it to the fire it will swell out, and become quite tense from the expansion of the contained air.

The principal source of caloric is the sun, whose beams, diffused through all nature by the refractive property of the atmosphere, are the source of vitality both to vegetables and animals, and when concentrated by a large convex lens, produce the most intense heat, sufficient to light a piece of diamond, and melt platinum. Caloric is also produced or evolved by combustion, by friction, percussion, chemical combination, electricity, and galvanism.

The evolution of heat by friction may be witnessed daily in a thousand instances. Lucifer matches are lighted by rubbing the

* It may be well to state here, that by *vapour* is generally understood the aerial form of a substance usually existing in a solid or fluid form at ordinary temperatures; as the vapour of iodine, a solid; of mercury, water, spirits, and other fluids; while the term *gas* is applied to those bodies usually known in the aerial state; thus oxygen, nitrogen, carbonic acid, hydrogen, &c. &c., are called gases. It is, however, but an arbitrary distinction; for many of these gases have, by the combined influence of cold and powerful pressure, been converted into fluids, and even solids—carbonic acid gas for instance!

highly inflammable substances with which they are tipped against a piece of sand-paper. Nearly all savage people procure fire by rubbing a piece of hard wood violently against a softer piece. The axle-trees of steam-engines, and even of carriages, have been known to be so heated by friction as to endanger burning the carriage; and it is very usual to be obliged to pour a quantity of cold water on the iron axle of the carriages of an express train after an hour of constant and rapid work. If you merely rub the blade of a knife rapidly on a piece of wood, it will become hot enough to burn your hand.

Percussion is merely a more energetic kind of friction, and is often resorted to by the blacksmith to light his furnace. He places a nail or other piece of soft iron on his anvil, and beats it rapidly with the hammer, when it becomes actually red hot. The production of sparks

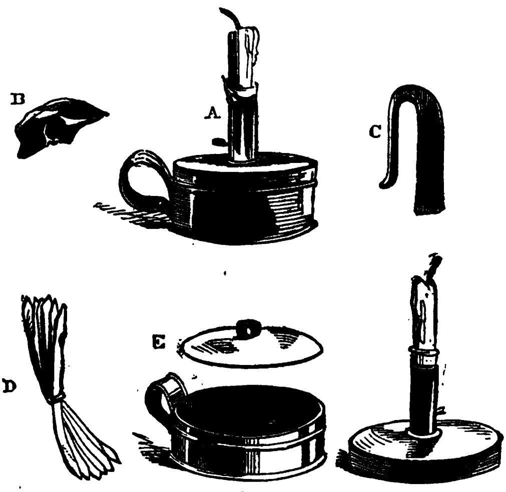

Fig. 20. C. The steel. B. The flint. E. The tinder. D. The matches of the old-fashioned tinder-box, A.

by striking flint against steel, or two pieces of flint one against the other, is a familiar instance of heat produced by percussion.

One of the most powerful means of producing heat is the process of combustion.

Combustion, as the word imports, is the *burning together* of two or more substances, a chemical union of oxygen generally with carbon and hydrogen in some shape or other. In our ordinary fires we burn coal, a hydro-carbon as it is called; and the gas which is now so

universally used for the purpose of illumination, is a compound of the same bodies—so wax, tallow, oil of various kinds, both of animal and vegetable origin, are all hydro-carbons.

On the application of a sufficient heat, and a free access of atmospheric air, or of some other gas containing oxygen in a certain state of combination, these bodies take fire, and continue to burn either with flame, or a red or even white heat without flame, until they are consumed; that is, until they have entered into new combinations with the oxygen, and are converted into carbonic acid and water, the carbon forming the first product, the hydrogen the other.

EXPERIMENTS PRODUCING HEAT AND COLD.

WATER is presented to us by nature in three forms, viz., in the conditions of ice, water, and steam, and many beautiful experiments can be made with it in either of these states.

Fig. 21. Snow crystals.

CRYSTALS OF SNOW.

Very few persons have any idea of the lovely forms they tread under foot when walking over fresh-fallen snow, or remember that frozen water is capable of assuming the three states of snow, hail, and ordinary ice.

The atmosphere always contains a considerable quantity of aqueous vapour, or invisible steam, which collects in the form of clouds, and in cold weather, in extra-tropical latitudes, descends in the form of snow, and covers the surface of the earth with a mantle of virgin white.

Snow has not only been seen in Europe, but has even visited China; and some years ago, a correspondent at Canton, writing to a friend, says: "The elders of our European society are, at this moment, in the ecstasy of revived associations, pelting each other with snowballs from the house-tops with all their might."

WATER DOES NOT CONTRACT WHEN REDUCED TO THE FREEZING POINT.

It is well known that solids usually expand by heat and contract by cold. This is proved by fitting a cold bar of metal into a gauge, and then heating it, when the bar will no longer enter the same space, and has therefore expanded.

Liquids, such as alcohol and mercury, follow the same law, as shown in the useful instrument called the thermometer; but water is a curious exception, and, after falling to a temperature of 40° F., begins to expand till it reaches a temperature of 32°, when it floats upon the surface of the warmer water, and thus protects the lower strata, containing the living insects, plants, and fish from the dangerous action of intense cold. The fact itself is proved by taking a long glass and nearly filling it with water. If a thermometer is placed at the bottom, the temperature may be, say 40°; whilst if a lump or two of ice be placed on the top, it floats and

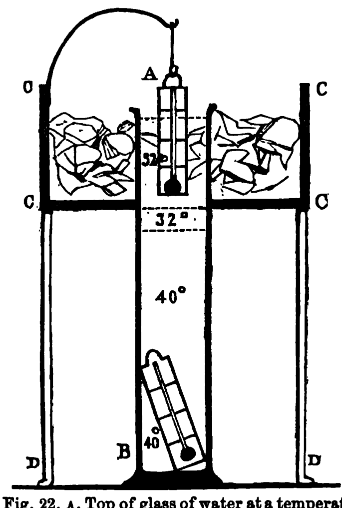

Fig. 22. A. Top of glass of water at a temperature of 32°, with lumps of ice floating. B. Bottom of water, and temperature at 40°. C C C C. Box, on legs, D D, containing a freezing mixture.

partly melts, reducing the temperature of the water to 32° Fah. Now, if the water contracted as it became colder, the particles would become more condensed or heavier, and hence they would sink to the bottom, and being succeeded by fresh quantities of warmer water, the whole volume would sink to the freezing point, or 32° Fah.: whereas they expand, become lighter, and swim on the surface of the warmer part of the fluid, like oil upon water.

FUSIBLE METAL EXPANDS UP TO A CERTAIN TEMPERATURE, AND CONTRACTS IF THE HEAT IS INCREASED.

Rose's fusible metal is made by melting one part of lead and mixing with it one part of tin and two parts of bismuth. A bar of this alloy expands till it attains a temperature of 111° Fahrenheit; it then rapidly contracts by the addition of heat, and at 156° attains its greatest density or contraction. After passing this temperature, the metal again expands, and melts at 201°, being eleven degrees below the boiling point of water. For that reason certain persons, of course wags, have taken the trouble to make spoons of it, and one may easily imagine the surprise of any grave person quietly stirring his or her tea, to see the spoon gradually disappear from their vision and sink in the liquid state to the bottom of the cup.

HOW TO EXAMINE THE VARIED CRYSTALLINE FORMS OF SNOW.

By collecting some snow on a black hat or a piece of black velvet and examining it by means of a magnifying glass, it is distinctly seen that they are not mere shapeless flakes, but possess crystalline forms of extreme beauty and of very great variety. In the Polar regions snow assumes the most beautiful and varied forms. Scoresby has figured ninety-six varieties, distributed into three classes; viz., *Lamellar*, or disposed in thin plates; *Spicular*, or dart-like, or sharp-pointed; and *Pyramidal* crystals. The snow crystals constantly vary, like the pictures of a kaleidoscope, and sometimes resemble parallel fillets, leaves, and spines with rosette terminations, as in Fig. 21, p. 26.

TO MAKE ICE IN SUMMER, AND LOWER THE TEMPERATURE OF WATER BY THE SUDDEN LIQUEFACTION OF A SOLID.

1st. Dissolve powdered nitre rapidly in water, when the temperature will fall from 50° to 35°. This fact is well known to experienced officers in hot climates, who thoroughly appreciate the value of a cartridge shaken gently over the neck of a bottle of wine standing in a pail of water. The cartridge contains nitre, which liquefies rapidly and cools the wine.

2nd. Two hundred and seven parts of lead, 118 of tin, and 284 of bismuth melted together and granulated (*i.e.* poured whilst liquid into water), will produce a temperature of 16° below the freezing point of water, if added rapidly to 1617 parts of quicksilver.

3rd. Four ounces of nitrate of ammonia, four ounces of carbonate of soda, dissolved in four ounces of water, will freeze water contained in a convenient thin metallic vessel surrounded with it.

HEAT PRODUCED BY THE SOLIDIFICATION OF A LIQUID.

Take some blue vitriol and heat it to redness in a crucible; when cold, place it in a well-stoppered bottle for use. If a little be put on a plate and sprinkled with cold water, steam issues in considerable quantity; and if a slice of phosphorus is placed on the surface of the blue vitriol, it will take fire in consequence of the latent heat set free by the chemical union of the water with the dry sulphate of copper or blue vitriol, when the water is in effect solidified. Ships laden with lime have taken fire from the leakage of the water, which combines with the lime, and produces a great heat.

HEAT PRODUCED BY THE CONDENSATION OF WATER.

A pint of water mixed with one pint of oil of vitriol generates a large amount of heat, and when cold does not measure two pints, showing that condensation has taken place.

DIFFERENCE BETWEEN LATENT AND SENSIBLE HEAT.

If a nail is made red hot, it glows with the ignition, and throws off heat, which is apparent to the senses; but if a cold horseshoe nail is examined, there is no direct evidence of the presence of heat; when, however, the same *cold* nail is rapidly hammered on an anvil, enough heat is obtained to set fire to a piece of phosphorus. The heat thus squeezed out by compression is called latent heat.

TO IMITATE HOAR-FROST.

Hoar-frost is caused by the freezing of the dew deposited on the branches and twigs of trees and bushes, and may be perfectly imitated by arranging some sprigs of holly or other plants on a wooden stand, in the centre of which is fitted a small evaporating dish containing some benzoic acid. On the application of heat, the acid is sublimed, and may be collected in a gas jar placed over the

Fig. 23. Circular wooden stand, B, with sprigs of holly, &c., inserted.

A. The gas jar, with stopper left sufficiently open to allow the benzoic acid vapour to escape a little.

C. The evaporating dish, containing the benzoic acid, and heated by the spirit lamp.

F. The sprigs of holly, rock-work, shells, &c.

stand and bits of holly; and as the vapour cools, a beautiful deposit of the crystals of benzoic acid on the miniature trees takes place. This experiment admits of a very tasteful arrangement, and after completion will last a long time, if protected by a glass shade.

THE BOILING OF ONE LIQUID MAY FREEZE ANOTHER.

To show that the heat abstracted by the boiling of one liquid will freeze another, fill a tall narrow glass about half full of cold water (the colder the better), and place in it a thin glass tube containing some ether. Put them under the receiver of an air-pump. As you exhaust the air, the ether will begin to boil, until at length, by continuing the exhaustion, the water immediately surrounding the tube of ether will freeze, and a tolerably large piece of ice may thus be obtained.

Ether evaporates so rapidly even under the pressure of the atmosphere, that a small animal such as a mouse may be actually frozen to death by constantly dropping ether upon it. If poured on the hand, it produces a degree of cold that soon becomes, to say the least, unpleasant.

Fig. 24.

EXPERIMENT.

Place a flat saucer, containing about a pound of oil of vitriol, under the receiver of the air-pump, and set in it a watch-glass containing a little water, supported on a stand with *glass* legs. Exhaust the receiver, when the water will evaporate, but without boiling, and the vapour being absorbed as it forms by the oil of vitriol, the vacuum is preserved, and the evaporation continues, until the vapour has abstracted so much caloric from the remainder of the water that it is all at once converted into ice.

In most elementary works on chemistry may be found a long table of freezing mixtures as they are called, some with and others without ice or snow. I have selected a few from each division.

FREEZING MIXTURES WITH ICE OR SNOW.

Snow or powdered ice	2	parts.
Powdered common salt	1	,,
Snow	5	,,
Powdered common salt	2	,,
Powdered sal ammoniac	1	,,
Snow	3	,,
Dilute sulphuric acid	2	,,
Snow	2	,,
Crystallized muriate of lime	3	,,

WITHOUT SNOW OR ICE.

Sulphate of soda	3	parts.
Dilute nitric acid	2	,,
Nitrate of ammonia	1	,,
Water	1	,,
Phosphate of soda	2	,,
Dilute nitric acid	1	,,
Sulphate of soda	2	,,
Muriatic acid	1	,,

The effects of most of these mixtures may be considerably increased by previously cooling the ingredients *separately* in other freezing mixtures.

CRYSTALLIZATION.

The ancients were unacquainted with the nature of crystals, and very far from having any just idea of the phenomena of crystallization; for Pliny, who flourished in the first century of the Christian era, speaks of the rock-crystal as a piece of ice frozen to the point of acquiring a permanent consistency and durability; when, in fact, the rock-crystal is composed of a mineral called silica, which crystallizes in six-sided prisms, terminating with six-sided pyramids.

The phenomena of crystallization, so replete with beauties, and so marvellous in their results, often take place within the reach of our observation; without, however, attracting it, from our ignorance of the circumstance. The substance which in cold and dry winter nights covers the panes of glass, exhibiting various fantastic and elegant ramifications, is the human breath crystallized. The pellucid and transparent coating which in the depth of winter covers and so elegantly decks the branches of trees and leaves of evergreens, is no more than crystallized water. The snow which falls and accumulates before our eyes, is a congeries or mass of an immense number of separate and transparent crystals of ice.

ALUM BASKETS.

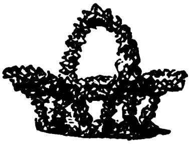

Fig. 25.

A common willow or wire basket may be covered with beautiful crystals, by immersing it in a solution of alum prepared for the purpose. The water used for the solution must be twice the quantity required to cover the basket, and sufficient alum put in to make a saturated solution, which you must filter through a piece of brown paper into a saucepan or pipkin. But if you wish your basket to be coloured, the dye must be added to the solution before it is filtered. To produce *Crimson* crystals, it is necessary to use an infusion of madder and cochineal. *Yellow*—Muriate of iron or turmeric. *Black*—Japan ink thickened with gum. *Blue*—A solution of indigo in sulphuric acid. *Pale Blue*—Equal portions of alum and blue vitriol; and to produce *green*, you have only to add to these last ingredients a few drops of muriate of iron. Of course, all these colours are more or less deep, according to the quantity of colouring matter employed.

The solution being filtered, boil it gently until half the quantity has been evaporated, then put it into a jar, or any other vessel in which the basket may be immersed, and remove it with its contents to a dry place, where it may cool without being disturbed.

It is to be observed that, if you make use of a wire basket, the wire must be filed or covered all over with worsted, as the surface of whatever is incrusted must be equally rough.

STARLIKE CRYSTALS.

Pour three ounces of diluted nitric acid into a glass vessel, and add to it gradually two ounces of bismuth broken by a hammer into small pieces. The metal will be attacked with great energy, and nitrate of bismuth will be formed. Crystallize the solution by a gentle heat, and preserve the crystals, which possess great beauty, under a glass.

BEAUTIFUL GROUPS OF CRYSTALS.

Dissolve in seven different tumblers, each containing warm water, half ounces of the sulphates of iron, copper, zinc, soda, alumina, magnesia, and potash. Pour them all, when completely dissolved, into a large evaporating dish of Wedgwood ware, and stir the whole with a glass rod; set the dish in a warm place, where it cannot be affected by the dust, and where it may not be agitated. When the necessary evaporation has taken place, the whole will shoot out into crystals. These will be interspersed in small groups, and single crystals amongst each other. Their colour and peculiar form of crystallization will distinguish each crystal separately, and the whole together, remaining in the respective places where they were deposited, will display a very curious and beautiful appearance. Preserve it carefully from dust.

CRYSTALS OF ALUM.

Dissolve a pound and a half of alum in a quart of boiling water, and suspend in it a piece of coke; set it aside to cool, and a beautiful crystallization, resembling a mineralogical specimen, will be obtained.

METALLIC CRYSTALLIZATION.

Melt a ladleful of bismuth, and let it cool gradually till a thin crust has formed on its surface; then, by means of a pointed iron, make two small apertures through the crust; quickly pour out by one of the openings the fluid portion, as carefully, and with as little motion of the mass as possible, whilst the air enters at the other. On removing the upper crust by means of a chisel, when the vessel has become cold, a cup-shaped concavity will appear, studded with very brilliant crystals, more or less regular, according to the quantity of bismuth employed, the tranquillity and slowness with which it cooled, and the dexterity with which the fluid portion, at the moment it began to harden, was decanted from the crystallized part. The same effect may be produced by fusing the substance in a small crucible which has a hole at its bottom, lightly closed by an iron rod or stopper, which is to be drawn out when the mass begins to congeal: by this means the superior portion, which is fluid, is made to run off, and a cake studded over with crystals is obtained.

CRYSTALS OF BLUE VITRIOL.

Boil a few copper filings in concentrated sulphuric acid, to which a small portion of nitric acid has been added, and when the copper is dissolved, dilute the mixture with a little water, and then leave it where it can cool gradually. If the mixture be then suffered to remain a few hours undisturbed, beautiful crystals of blue vitriol will be found at the bottom of the vessel, as hard as some minerals.

CRYSTALLIZATION ON INSECTS, FLOWERS, MOSSES, &c.

The application of aluminous crystallization to objects of natural history and botany has opened a wide field of amusement in a subject heretofore possessing little variety, inasmuch as baskets have been nearly the only articles subjected to the process of crystallization.

Put eighteen ounces of alum into a quart of water (keeping the same proportions for a greater or less quantity), and dissolve it by simmering it gently in a close tinned vessel over a moderate fire, stirring it frequently with a wooden spoon.

When the solution is completed, it must be poured into a deep glazed jar, and as it cools, the subjects intended to be crystallized should be suspended in it by a piece of thread or twine, from a stick laid across the mouth of the jar; where they must be suffered to remain for twenty-four hours. When taken out of the solution, they are to be hung up in a shady, cool situation, till perfectly dry. Care must be taken that the solution is neither too hot nor quite

cold, as in the one case the crystals will be very small, and in the other much too large.

The insects adapted for crystallization are spiders, beetles, and grasshoppers; and amongst the vegetable productions the common moss-rose, bunches of hops, ears of corn, the daisy, hyacinth, pink, furze blossoms, lichens, and mosses are some of the most suitable subjects; the nests of small birds, with their eggs, particularly if fastened on the branch of a tree, are exceedingly interesting. It is necessary to observe that much attention must be paid to the deposition of the alum, to see that too great a quantity does not settle upon some parts, and too little upon others.

OXY-CHLORIDE OF LEAD.

Melt in the bowl of a tobacco-pipe, or in a small crucible, a mixture of an ounce of litharge of lead, and a drachm of pulverized muriate of ammonia; when well incorporated by exposure to a red heat, pour it into a metallic cup, and allow it to cool: the result will be oxy-chloride of lead of a bright yellow colour, which, when broken, will present a most beautiful crystalline appearance.

CRYSTALS OF GLAUBER SALTS.

On a solution of common soda pour, by small quantities at a time, diluted sulphuric acid, until the effervescence ceases; by gently evaporating the solution in a saucer near a fire, crystals of sulphate of soda (Glauber salts) will be obtained.

COMMON SALT.

Take some muriatic acid, and mix it with thrice its bulk of water, adding thereto as much soda as it will dissolve; by slowly evaporating the solution before the fire, muriate of soda (common table salt) will be obtained.

TO MAKE LARGE CRYSTALS.

The salt to be crystallized is to be dissolved in water, and evaporated to such a consistency that it shall crystallize on cooling. Set it by, and when quite cold, pour the liquid part from the mass of crystals at the bottom, and put it into a flat-bottomed vessel. Solitary crystals will form at some distance from each other, and gradually increase in size. Pick out the most regular, put them into another flat-bottomed vessel, a little apart from each other, and pour over them a quantity of fresh solution of the salt evaporated, till it crystallizes on cooling. Alter the position of every crystal once at least every day, with a glass rod, that all the faces may be alternately exposed to the action of the liquid; for the face on which the crystal rests never receives any increase. By this process the crystals will gradually augment in size. When they have acquired such a magnitude that their forms can easily be distinguished, the most regular are to be chosen, or those which have the exact shape which you wish to obtain. Each of them should be put separately into

a vessel filled with a portion of the same liquid, and turned by the glass rod several times a day, and by this treatment you may obtain them almost of any size desired. Whenever it is observed that the angles and edges of the crystals become blunted, the liquid must immediately be poured off, and fresh liquid put in its place, otherwise the crystal will be infallibly destroyed.

LEAD TREE.

Dissolve two drachms of acetate of lead in a quart of water, and set it aside for a day or two, decant the clear solution into a large phial, and in the centre suspend a piece of zinc, by means of a silk thread fixed to the cork. If the whole be left undisturbed, the lead will arrange itself around the zinc in beautiful metallic plates, resembling a shrub.

ARBOR DIANÆ, OR SILVER TREE.

Let six drachms of a saturated solution of pure silver in nitric acid, and four drachms of a similar solution of mercury in the same acid, be diluted with five ounces of distilled water, and poured into a small decanter or glass phial; then compose an amalgam, by mixing one part of finely-divided silver with seven parts of mercury, and place a small lump of it at the bottom of the bottle, which must be kept quite still. In a short time the surface of the amalgam will be covered with minute filaments of silver, and after standing about forty-eight hours, the solution will deposit all its silver, in the form of brilliant, arborescent crystals, springing like a glittering shrub from the bottom of the vessel.

Fig. 26. Engraver's globe, with arborescent precipitate of silver.

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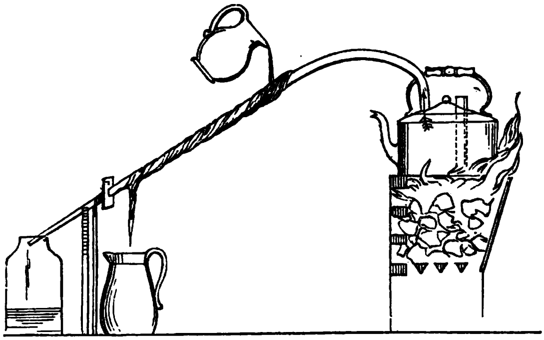

Fig. 28. The tea-kettle-still at work: the kettle is shown in section; the arrow shows direction of the steam.

TO PROCURE HYDROGEN GAS.

Into a common wine-bottle, provided with a cork and pewter tube, place some granulated zinc or zinc cuttings; fill the bottle about half full with water, and add some oil of vitriol; when effervescence takes place from the escape of hydrogen gas, which may be collected in gas jars on the pneumatic trough, the same as oxygen gas, by fitting in the cork and tube.

CARE MUST BE TAKEN IN BURNING HYDROGEN FROM THE GENERATING BOTTLE.

If it is desired to see the hydrogen burn from the end of the pewter pipe, it should be turned up straight, and before applying flame the first portion of the gas must be allowed to escape, or else the air already in the bottle mixes with the hydrogen and forms an explosive mixture, and if this is fired, the cork and pewter pipe are blown to the ceiling, whilst the bottle is frequently broken and the acid spilled about. A case occurred where some boys, making hydrogen in their bedroom in an ink-bottle, with a tobacco-pipe stem for a jet, incautiously applied the flame, when the whole exploded, and one of the poor boys lost his eyesight.

FIRE ON WATER.

Take a finger-glass, and after putting in plenty of granulated zinc, pour on some water and oil of vitriol, when a powerful effervescence takes place, and the liquid boils over the sides of the glass, which should stand in a soup-plate. Flame applied sets fire to the bubbles of escaping hydrogen, that dart over the whole surface, and produce a number of slight explosions. This experiment should be performed under a chimney or in the open air, as the acid smoke, or rather steam, is very disagreeable.

Fig. 29. The jar of hydrogen and the toy in hand.

EXPERIMENTS WITH HYDROGEN.

When a gas jar is filled with hydrogen, it may be lifted carefully from the pneumatic trough without fear of any gas escaping, and placed on a stand sufficiently high to admit of the hand being inserted into the jar; if one of the squeaking toys be first worked in the air and then in the jar of hydrogen, the effect is very laughable, as the sound becomes so shrill, in consequence of the levity of the gas. A bell sounded in air and afterwards in hydrogen is also an amusing experiment.

CURIOUS SOUNDS EMITTED BY BURNING HYDROGEN FROM A JET OVER WHICH GLASS TUBES OF VARIOUS SIZES ARE PLACED.

Take the generating hydrogen bottle, and fit a long jet with a small orifice; if the hydrogen is set on fire, and a tube placed over it at a certain place, the hydrogen flame begins to flicker and emit a sharp sound, which is varied according to the length and diameter of the glass tubes. Sometimes many tubes may be tried before the sound can be obtained.

SYNTHESIS OF HYDROGEN AND OXYGEN, AND FORMATION OF WATER.

If the jet over which hydrogen is burning is held under a cold glass jar, the steam is very soon condensed, and trickles down the sides in drops of water, produced by the combination of the hydrogen with the oxygen of the air, as every nine pounds of water consist of eight of oxygen and one of hydrogen.

EXPERIMENTS WITH OTHER GASES.

NITROUS OXIDE, OR LAUGHING-GAS, AND NITRIC OXIDE GAS.

TAKE two or three ounces of pure nitrate of ammonia in crystals, and put them into a retort, then apply the heat of a lamp to the retort, and take care that the heat does not exceed 500°. When the crystals begin to melt, nitrous oxide gas will be evolved in considerable quantities. Nitric oxide gas may be produced by pouring nitric acid, diluted with six times its weight of water, on copper filings, or small pieces of tin. The gas is evolved until the acid is saturated with oxide of copper, when the process may be stopped.

To inhale Laughing-gas.—Procure an oiled or varnished silk bag, or a bladder furnished with a stop-cock; fill it with pure nitrous oxide, and after emptying the lungs of common air, take the stop-cock into the mouth, and at the same time hold the nostrils; the sensations produced will be of a highly pleasing nature. A great propensity to laughter, a rapid flow of vivid ideas, and an unusual fitness for muscular exertion, are the ordinary feelings which it generally produces. The sensations produced by breathing this gas are not the same in all persons, but they are always of an agreeable nature, and not followed by any depression of spirits, like those occasioned by fermented liquors. Although no accident has yet happened to any one whilst inhaling laughing-gas, it is perhaps better to leave such experiments to be performed by experienced persons only. Nitric oxide gas nearly caused the death of Sir H. Davy, who tried to inhale it; but the orange-red fumes of nitrous acids formed when it comes in contact with the air almost suffocated him.

COAL GAS.

Fill the bowl of a large tobacco-pipe with pulverized coal, and stop it close with a mixture of pipe-clay and sand; then put it into a clear fire, and in a few minutes carburetted hydrogen gas will issue from the end of the pipe, which may be ignited, and will burn like a taper, affording an example of the production of gas-light.

VIOLET-COLOURED VAPOUR.

Put three or four grains of iodine into a small test tube, and seal the other end of it hermetically. If the tube be gently warmed, by holding it over a candle, the iodine will become converted into a beautiful violet-coloured gas or vapour, which, when the tube is suffered to cool, condenses again into minute brilliant metallic crystals of a bluish colour. This experiment may be repeated with the same tube and iodine for any number of times.

CHLORINE.

The other simple gas called a supporter of combustion is named chlorine, from a Greek word signifying yellowish green.

This gas was formerly called "oxymuriatic acid," being supposed to be a compound of oxygen and muriatic acid gases, until Sir H. Davy, in a series of masterly experiments carried on during the years 1808–9–10–11, proved that it contained no oxygen

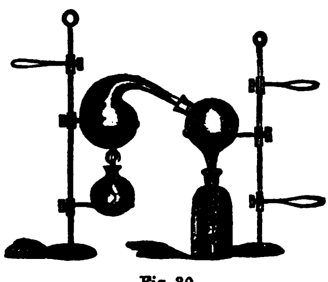

Fig. 30.

or muriatic acid, and that it was in fact a simple or undecompounded substance, and changed its name to chlorine, which name was, after some discussion, accepted by the scientific world, and is still in use.

This gas may be obtained for experiment, by gently heating in a retort a mixture of muriatic or hydrochloric acid, as it is now called, with some black oxide of manganese: the muriatic acid, a compound of chlorine and hydrogen, is decomposed, and so is the oxide of manganese, giving out some of its oxygen, which takes the hydrogen from the muriatic acid to form water, while the chlorine gas, with which the hydrogen had been united, is set at liberty, and may be collected in jars over water.

Chlorine gas is transparent, of a greenish yellow colour, has a peculiar disagreeable taste and smell, and if breathed even in small quantities, occasions a sensation of suffocation, of tightness in the chest, and violent coughing, attended with great prostration. I have been compelled to retire to bed from having upset a bottle containing some of this gas. It destroys most vegetable colours when moist, and is in fact the agent now universally employed for bleaching purposes.

It has also the power of combining with and destroying all noxious smells, and is invaluable as a purifier of foul rooms, and destroyer of infection. For these latter purposes it is used in combination with lime, either in substance or solution, under the name of "Chloride of Lime."

Sir W. Burnett has lately discovered that the chloride of zinc answers the same purposes as the chloride of lime, and has the advantage of being itself destitute of smell, and his fluid is frequently substituted for the other.

Chlorine gas is a powerful supporter of combustion, many of the metals taking fire spontaneously when introduced in a fine state of division into the gas.

EXPERIMENTS.

1. Into a jar of chlorine gas introduce a few sheets of copper leaf, sold under the name of Dutch foil, when it will burn with a dull red light.

2. If some metallic antimony in a state of powder be poured into a jar of this gas, it will take fire as it falls, and burn with a bright white light.

3. A small piece of the metal potassium may be introduced, and will also take fire.

4. A piece of phosphorus will also generally take fire spontaneously when introduced into this gas. In all these cases direct compounds of the substances with chlorine are produced, called chlorides.

5. If a lighted paper be plunged quickly into the gas, it will continue to burn with a dull light, giving off a very large quantity of smoke, being in fact the carbon of the wax taper, with which the chlorine does not unite; while the other constituent of the taper, the hydrogen, forms muriatic acid by union with the chlorine.

6. This substance has the property of destroying most vegetable

colours, and is used in large quantities for bleaching calico, linen, and the rags of which paper is made. It is a curious fact that it shows this property only when water is present, for if a piece of coloured cloth is introduced dry into a jar of the gas, also dry, no effect will be produced—wet the cloth, and re-introduce it, and in a very short time its colour will be discharged.

7. Introduce a quantity of the infusion of the common red cabbage, which is of a beautiful blue colour, into a jar of this gas, and it will instantly become nearly as pale as water, retaining a slight tinge of yellow.

EXPERIMENTS WITH CARBON AND OXYGEN.

CARBON forms two gaseous compounds with oxygen; the first, called carbonic oxide, is not difficult to procure, but possesses no interesting properties. It is inflammable.

The other compound, carbonic acid, is transparent, colourless, much heavier than atmospheric air, has an agreeable taste, has the power of irritating the mucous membrane of the nose (as any one can tell who has drunk soda-water), without possessing any particular odour, is absorbed by water, does not support respiration, and extinguishes burning bodies.

Carbonic acid gas may be obtained with the greatest facility by pouring some sulphuric acid, diluted with about six parts of water, upon some pieces of marble or limestone in a bottle with a tube attached, when the gas comes over in torrents. It may be collected over water, or allowed to fall into a bottle.

EXPERIMENTS.

1. To show the great comparative weight of this gas, place a lighted taper at the bottom of a tall glass jar, then take a jar full of carbonic acid gas, and pour it as you would pour water into the jar containing the lighted taper; you will soon find the taper will be extinguished as effectually as if you had poured water on it, and the smoke of the taper will float on the surface of the gas in very beautiful wavy forms.

2. Heat a piece of the metal potassium in a metal spoon (platinum is best), and if introduced in a state of ignition into the gas, it will continue burning brilliantly, producing a quantity of dense smoke, which is the carbon from the carbonic acid, the potassium having seized the oxygen and being converted by it into potash.

Fig. 31. Stoppered bottle for holding gas.

3. If a mouse, bird, or other small animal, be placed in a jar of this gas, it becomes insensible almost immediately, but if speedily removed it will occasionally recover.

4. Shake up some water with some of this gas in a bottle; the greater part of the gas will be absorbed by the water,

which acquires a sparkling appearance and a pleasant sharp taste ; with the addition of a little soda this becomes the well-known beverage called soda water, so famous for removing the morning headaches caused by "*that salmon*" having disagreed at yesterday's dinner !

CARBONIC ACID GAS.

It is the presence of this gas which renders it so dangerous to descend into deep wells, for by its great weight it collects at the bottom, and instantly suffocates any unfortunate person who incautiously subjects himself to it. Hence it is prudent always to let down a lighted candle before any one descends into a well, or other deep excavation, and if the candle is extinguished, it is necessary to throw down several pails of water, lime-water if possible, and again to try the candle, which must burn freely before it is safe for any one to descend.

It is this same gas, under the name of "choke-damp," which proves so dangerous to miners, particularly after an explosion of "fire-damp," for it is the principal product of the explosion, and by its weight settles at the bottom of the mine, whence it is by no means an easy matter to dislodge it.

Carbonic acid gas has been condensed into the fluid form by causing it to be disengaged under great pressure ; the fluid acid has the appearance of water. When the pressure is removed, as by allowing some of the fluid acid to escape from the vessel in which it has been condensed, it instantly reassumes the gaseous form, and in so doing absorbs so much latent caloric that a portion of the acid is actually solidified, and appears in the shape of *snow*, which may be collected and preserved for a short time. After a lecture by Mr. Addams before the Ashmolean Society of Oxford, a kind of *snowball* of carbonic acid was carried for a distance of 500 or 600 yards, and placed in a saucer in a room. It evaporated very rapidly, and left no residue, not even a mark where it had lain. It was too *cold* to be touched by the naked hand without pain.

Carbonic acid and lime are mutually tests for each other. If a jar containing a little lime-water be put into a jar of this gas, it speedily becomes turbid, the gas uniting with the lime, and producing chalk (the carbonate of lime), which is insoluble in water.

This gas is produced in large quantities by the respiration of animals, as may be proved by respiring through a tube immersed in lime-water, when the water will be instantly rendered turbid from the formation of chalk.

CARBON AND HYDROGEN.

To the combination of these elements in various proportions, and with the occasional addition of other substances, we are indebted for all, or nearly all, our means of obtaining light and heat. Coal, wood, spirit, oil, and all the varieties of fats, are composed principally of carbon and hydrogen, and may easily be converted into the gas with which our houses and streets are lighted, which is nearly pure carburetted hydrogen.

There are but two definite gaseous compounds of these two elements, the carburetted hydrogen, and bicarburetted or olefiant gas. The first is easily procured by stirring the bottom of stagnant water in a hot summer's day, and collecting the bubbles in a bottle filled with water and inverted over the place where the bubbles rise. This gas burns with a yellowish flame, and when mixed with a certain proportion of air, or oxygen gas, explodes with great violence on the application of a flame. It is the much-dreaded fire-damp generated so profusely in some coal-mines, and causing such fearful destruction to life and property when accidentally inflamed. It is this gas also, in a state of low combustion, which produces the lambent flame frequently seen in the evenings hovering over marshes, and called the "Will-o'-the-wisp." This appearance is still regarded with superstitious horror by the uneducated countryman.

The other compound, the bicarburetted hydrogen, forms by far the principal part of the gas used for illumination; and, in fact, whatever substance is employed for artificial light, whether oil, tallow, wax, &c. &c., it is converted into this gas by heat, and then furnishes the light by its own combustion.

This gas has some very curious properties, and may be obtained nearly pure by mixing in a retort, *very carefully,* one part of spirits of wine and four of sulphuric acid. The heat produced by the mixture being insufficient to decompose the spirit, a lamp must be placed under the retort, when the gas will speedily be disengaged, and will come over in great abundance; it may be collected over water.

This gas is transparent, colourless, will not support combustion, but is itself inflammable, burning with a brilliant white light, and being converted into carbonic acid and water. If mixed with three or four times its bulk of oxygen, or with common atmospheric air in much larger proportions, it explodes with great violence.

This gas is sometimes called "olefiant gas," from the property it possesses of forming an oily substance when mixed with chlorine.

EXPERIMENT.

Into a jar standing over water half-full of this gas, pass an equal quantity of chlorine gas. The gases will speedily unite and form an oily-looking liquid, which may be collected from the sides of the jar as it trickles down. By continually supplying the jar with the two gases as they combine, a considerable quantity of this substance may be collected. Care should be taken that the olefiant gas is rather in excess.

The substance produced is insoluble in water, with which it should be washed by shaking them together in a tube, and has a pleasant sweetish taste and aromatic smell, somewhat resembling ether.

Fig. 32.

COAL GAS.

The gas so universally employed for the purposes of illumination is a mixture of the carburetted and bicarburetted hydrogen, with minute portions of other gases scarcely worth mentioning. It is procured by submitting coals to a red heat in iron retorts, having a tube passing from one end, along which passes all the fluid and gaseous matter separated from the coal,—namely, gas tar, ammoniacal liquor, and various gases, carburetted hydrogen, carbonic acid, sulphuretted hydrogen, sulphurous acid, &c. &c. The tar and ammoniacal liquor remain in the vessel in which the tubes from the retorts terminate, and the gaseous productions are conveyed through water and lime to separate the impurities; the remaining gas, now fit for use, passes into large iron vessels, called gasometers, inverted over water (like the jars in a pneumatic trough), whence it is sent through pipes and distributed where required. What remains in the retorts is called coke. It consists principally of charcoal, mixed with the earthy and metallic particles contained in the coal.

EXPERIMENT.

If you possess an iron bottle, fill it with powdered coal, and attach a flexible tube to it, and put it in the fire: as soon as it becomes red hot, large quantities of smoke will escape from the end of the tube, being the gas mixed with all its impurities. By passing it through water (if mixed with lime it will be better), the gas may be collected in jars standing over water, and submitted to experiment. If you do not possess a bottle, take a tobacco-pipe with a large bowl (a "churchwarden," for example); fill the bowl with small coal, cover it with clay or putty, and when dry put it into the fire, and the gas will soon appear at the other end of the pipe, when it may be lighted, or the gas may be collected over water, as in the former experiment.

This gas is given off spontaneously in some coal-mines, and as it forms explosive mixtures with atmospheric air, the mines where it abounds could not be worked except at the greatest risk until about the beginning of the present century, when Sir H. Davy, while prosecuting some researches on the nature of flame, found that flame would not pass through metallic tubes, and he gradually reduced the length of the tubes, until he found fine iron wire gauze formed an effectual barrier against the passage of flame. He then thought that if the light in a lantern were surrounded with this gauze, it might safely be used in an inflammable atmosphere where a naked light would instantly cause an explosion. Upon submitting the lamp to experiment, he found that by passing coal gas by degrees into a vessel in which one of his lamps was suspended, the flame first became much larger, and then was extinguished, the cylinder of gauze being filled with a pale flame, and though the gauze sometimes became red-hot, it did not ignite the gas outside. As the supply of coal-gas was diminished, the wick of the lamp was rekindled, and all went on as at first. A coil of platinum wire

was afterwards suspended in the lamps, which becomes intensely heated by the burning gas, and gives out sufficient light to enable the miner to see to work. As long as the gauze is perfect, it is impossible for the external air to be kindled by the wick of the lamp, but the miners are so careless, that they will often remove the gauze to get a better light, to look for a tool, or some cause equally trivial, and many lives have been lost in consequence of such carelessness.

The effect of fine wire-gauze in preventing the passage of flame may be shown by bringing a piece of the gauze gradually over the flame of a spirit-lamp, until it nearly touches the wick, when the flame will be nearly extinguished, but the vapour of the spirit passes through, and may be lighted on the upper side of the gauze, which will thus have a flame on either side, though totally unconnected with each other. The flame from a gas-burner will answer as well as the spirit-lamp.

Nearly all the fluids, and solids also, used for procuring artificial light, such as naphtha, various oils, tallow, wax, spermaceti, spirits of wine, ether, &c. &c., are compounds of carbon and hydrogen in different proportions, with the occasional addition of some other elements, especially oxygen and hydrogen, in the proportions to form water; as a general rule, those bodies containing the greatest proportion of carbon give the most light, though not necessarily the most heat.

MISCELLANEOUS EXPERIMENTS.

HEAT.

1. Put some water into a glass or cup, and pour upon it about half the quantity of sulphuric acid; upon stirring them together, the temperature will rise to many degrees above boiling water. In mixing the acid with the water, the greatest care should be taken not to do it too suddenly, as the vessel may break from the sudden heat, and the acid be spilt on the hands, clothes, &c. The greatest caution is also necessary in using it, as it will attack nearly every organic thing it is dropped on.—If a piece of iron is hammered smartly on an anvil, its latent heat will be evolved in a short time to such a degree, that the iron will become almost red hot.—Pour a little clear water into a small glass tumbler, and put one or two pieces of phosphuret of lime into it. In a short time, flashes of fire will dart from the surface of the water, and terminate in ringlets of smoke, ascending in regular succession.

2. Thinly spread some dry nitrate of copper on a piece of tin foil, three or four inches square, and wrap it up; there will not be any effect produced. Unfold the tinfoil, and sprinkle a very small quantity of water on the nitrate of copper, wrap it up again as quickly as possible, and press down the edges closely. Considerable heat, attended with fumes, will now be evolved; and if the experiment be dexterously managed, it will ignite. This shows that nitrate

of copper has not any effect on tin till in a state of solution.—Fill a saucer with water, and drop a small piece of potassium into it; the instant it touches the water, it will burst, with a slight explosion, into a brilliant, violet-coloured flame. It will continue burning for a short time on the surface of the water, darting from one side of the vessel to the other with great violence, like a beautiful fire-ball. If the potassium is thrown upon ice, it will likewise instantly take fire.—Pulverize separately one ounce of crystallized muriate of ammonia, an equal quantity of nitrate of potash, and two ounces of sulphate of soda; mix them together in a goblet with four ounces of cold water, and immediately immerse in the mixture a thin glass tube containing cold water; in a short time it will freeze, even in a warm room, or in the midst of summer.

3. Take a very thin glass bulb, half-filled with water, and continue to drop ether so slowly upon it, that it may evaporate, and not fall from the surface of the glass; the water inside will quickly be frozen, and this effect will take place sooner if the bulb is held in a current of air.

4. Water expands by cold as well as by heat, and to prove this, it is only necessary to expose a phial filled with water, closely corked, in a frosty night; when the water is frozen, the glass will burst.—Put into a wine-glass a few tea-spoonfuls of a concentrated solution of silicate of potash, and add to it gradually, drop by drop, sulphuric acid. If these two liquids be stirred together with a glass rod, they will become converted into an opaque, white, and almost solid mass.

5. Pour a small quantity of water in some muriate of lime, just sufficient to saturate, not liquefy it; then let some concentrated sulphuric acid fall gradually upon this solution, and a solid compound, called sulphate of lime will be produced.

PRINCE RUPERT'S DROPS.

Fig. 33.

Glass is an extremely bad conductor of heat, and the reason why tumblers and other vessels made of glass crack when hot water is suddenly poured into them is, that the interior of the glass expands before the heat can penetrate through the particles on the outside, which are consequently then riven asunder. Small glass toys called Prince Rupert's drops, which may be obtained at a glass-blower's, show very clearly the effect of heat on bad conductors. They are made by dropping a small quantity of glass, while almost in a liquid state, into water, by which means a globule with a spiral tail is instantly formed; the outside of the globule cools and solidifies the instant it comes into contact with the water, before the inner part changes, and this, as it gradually hardens, would contract, were it not retained and kept in its form by its adherence to the outer crust. If the tail is broken off, or any other injury done to the globule, it will burst with a slight noise and fall to pieces. In order that glass ware may be durable, it is annealed; that is to say, it is put into an oven the temperature of which is allowed to decrease gradually.

ATTRACTION AND DECOMPOSITION.

1. Add a little water impregnated with carbonic acid to a wine-glass of clear lime-water : these two liquids will combine and form a white substance, which is called carbonate of lime.—Throw a piece of copper into a wine-glass, and pour upon it some nitric acid ; these two substances will combine, and a solution of a clear blue colour will be produced. If you plunge into it a piece of iron (the blade of a knife will answer), the acid will combine with this new body, and the copper will be precipitated on the blade of the knife in its original state. Should the solution be allowed to remain undisturbed for some days, it will crystallize, and salts of copper will be produced.

2. Pour a little of the infusion of litmus, or of red cabbage, into a wine-glass, and add to it a single drop of nitric or sulphuric acid, and it will be instantly changed into a beautiful red colour.

3. Take a little of the liquid mentioned in the above experiment, either before or after it has been converted to red, add to it a few drops of the solution of potash, or soda, and, upon stirring it up, a fine green colour will be produced.

4. Let a drop of nitrate of copper fall into a glass and then fill it up with water, it will be perfectly colourless; but upon putting a drop of liquid ammonia, which is also without colour, into the glass, the liquid will change to a beautiful deep blue.

5. Take some of the blue liquid left by the former experiment, and let a drop or two of nitric acid fall into it, and it will become clear as crystal.

6. A drop of nitrate of copper poured into a glass of water will not produce any change in the colour of the fluid, but if a small crystal, or a drop of the solution of prussiate of potash be added, the water will become a dark brown.

7. Mix some powdered manganese with a little nitre, and throw the mixture into a red-hot crucible, and a compound will be obtained possessed of the singular property of changing to different colours, according to the quantity of water that is added to it. A small quantity gives a green solution, whilst a greater quantity changes it to a beautiful rich purple. The last experiment may be varied by putting equal quantities of this substance into separate glasses, and pouring hot water in the one, and a portion of cold water in the other. The hot solution will assume a beautiful green colour, and the cold one a deep purple.

8. By pouring lime-water on to some juice of beet-root, a colourless liquid is obtained ; but if a white cloth be dipped in the liquid and dried, in a few hours it will become quite red, by the mere contact of the air.

9. Spirits of hartshorn dropped into a solution of copper so weak as to be almost colourless, will produce an intense blue, which disappears by adding an acid.

10. *To make Soap.*—Pour a little water into a phial containing about an ounce of olive oil; shake the phial, and if the contents are examined, it will be found that no union has taken place ; but if

some solution of caustic potash is added, and the phial then shaken, an intimate combination of the materials occurs, and soap is produced.

11. Pour a little nitro-muriatic acid upon a small piece of gold, or gold leaf, and in a short time it will be completely dissolved, and the solution will assume a beautiful yellow colour.

12. Pour a small quantity of nitric acid upon a little bit of pure silver, or silver leaf, and it will dissolve in a few minutes.

13. Pour a little sulphuric acid, diluted with about four times its bulk of water, upon a few iron filings; a strong effervescence, caused by the escape of hydrogen gas, will take place, and in a little time the filings will disappear.

14. Pour some diluted nitric acid on a piece of copper, and in a little while the copper will be dissolved, and the solution will become of a beautiful blue tint.

15. Into a solution of nitrate of silver immerse a small bar of polished copper; on withdrawing the bar, it will be found to be covered with a fine coating of metallic silver.

16. A small bar of polished iron immersed in like manner in a solution of nitrate of copper will receive a coating of metallic copper.

17. A piece of silver immersed in the above solution will remain unchanged; but if immersed in contact with a piece of iron, both, when withdrawn, will be found to be covered with a coating of metallic copper.

18. Pour half an ounce of diluted nitro-muriate of gold into an ale-glass, and put in it a piece of very smooth charcoal. Expose the glass to the rays of the sun, in a warm place; and in a short time the charcoal will be covered over with a beautiful golden coat. Take it out with a pair of pincers, and enclose it in a glass for show.

TO MELT A COIN IN A NUT-SHELL.

Mix three parts of dried nitre, one of sulphur, and one of fine dry sawdust, and pound them well in a mortar. Press a portion of this powder into a walnut-shell, and also enclose within the shell a thin piece of silver, or copper rolled up; then fill the shell with some more powder, press it down closely, and set fire to it; the piece of metal will soon be melted, whilst the nut-shell is merely blackened.

TO RENDER THE SURFACE OF WATER PHOSPHORESCENT.

Wet a lump of fine loaf sugar with phosphorized ether, and throw it into a basin of water; the surface of the water will become luminous, and show beautifully in the dark: by gently blowing upon it, phosphorescent undulations will be formed, which will illumine the air above the fluid for a considerable space. In winter the water must be rendered blood-warm. If the phosphorized ether be applied to the hands (which may be done with safety), it renders them luminous in the dark.

LUMINOUS WRITING IN THE DARK.

Put a small piece of solid phosphorus into a quill, and write with it upon paper; if carried into a dark room, the writing will appear luminous, and have a beautiful effect. Should the phosphorus take fire by the friction, it must be plunged immediately under the surface of water and extinguished; if any burning phosphorus falls upon the hands, the painful effects of the severe burn are greatly mitigated by plunging them under the surface of water to which a very little solution of ammonia has been added.

SEMBLANCE OF PERPETUAL MOTION.

Into a basin of clean water put a few pieces of camphor; they will commence a peculiar motion, traversing every part of the surface of the water; but may instantly be stopped by dropping into the water the minutest quantity of an oily substance.

ARTIFICIAL PETRIFACTIONS.

Put into a retort a quantity of pounded fluor spar and sand, and pour upon it some sulphuric acid; fluosilicic acid gas will be disengaged, holding silex in solution. The subjects that you wish to resemble petrifactions must next be moistened with water, and placed in a vessel connected with the neck of the retort. The fluosilicic acid gas will be absorbed by the moisture adhering to the substances, and the silex will be precipitated upon them like a sort of hoar-frost, which will have a beautiful appearance, and be tolerably durable.

BEAUTIFUL EXPERIMENT WITH PHOSPHORUS.

Fig. 34.

Put half a drachm of solid phosphorus into a Florence oil flask, holding the flask slantingly, that the phosphorus may not break the glass; pour upon it a gill and a half of water, and place the whole over a tea-kettle lamp, or any common lamp, filled with spirits of wine; light the wick, which should be about half an inch from the flask; and as soon as the water is boiling hot, streams of fire resembling sky-rockets will burst at intervals from the water; some particles will also adhere to the sides of the glass, and immediately display brilliant rays, and thus continue until the water begins to simmer, when a beautiful imitation of the aurora borealis will commence, and gradually ascend until it collects into a pointed cone at the mouth of the flask: when it has continued for half a minute, blow out the flame of the lamp, and the apex of fire that was formed at the mouth of the flask will rush down, forming beautiful illumined clouds of fire

rolling over each other for some time, and when these disappear, a splendid hemisphere of stars will present itself. After waiting a minute or two, light the lamp again, and nearly the same phenomena will be displayed as from the beginning. Let a repetition of lighting and blowing out the lamp be made for three or four times, so that the number of stars may be increased, and after the third or fourth time of blowing out the lamp, the internal surface of the flask will be dry. Many of the stars will shoot with great splendour from side to side, whilst others will appear and burst at the mouth of the flask. What liquid remains in the flask will serve for the same experiment three or four times without adding any more water. Care should be taken, after the operation is over, to put the flask in a secure place.

SYMPATHETIC INKS.

All writings or drawings executed with sympathetic inks are illegible until by the action of heat or some chemical agents upon a peculiar acid or substance which forms the basis of the ink, a change is effected, and a colour produced from that which was before colourless.

1. Write with a weak solution of sulphate of iron, and it will be invisible; when dry, wash it over with a solution of prussiate of potash, and the writing will be restored, and turned to a beautiful blue.

2. Write with some of the above solution, and it will, as before stated, become invisible, but if a brush which has been dipped in a decoction of oak bark, or tincture of galls, be slightly passed over it, it will turn black.

3. Write with the nitro-muriate of gold, and brush the letters over with muriate of tin in a diluted state. The writing, before invisible, will then appear of an exquisitely beautiful purple colour.

4. The most curious of all kinds of sympathetic ink is that procured from cobalt. It is a very singular phenomenon, peculiar to this ink, that the characters of figures traced out with it may be made to appear and disappear at pleasure; all other kinds of sympathetic ink are at first invisible, until some fluid has been applied to cause their re-appearance, but when once they are developed, they remain permanent. To make this ink, take zaffre, and dissolve it in nitro-muriatic acid, until the acid extracts from it the metallic part, or cobalt, which communicates to the zaffre its blue colour; then dilute the solution, which is very acrid, with common water. If you write with this preparation, the characters will be invisible; but when exposed to a moderate degree of heat, they will become green, and on the paper cooling again, they will vanish. However, if the paper is over-heated, the writing will not disappear.

5. Write with a diluted solution of muriate of copper, and the writing will be invisible, when dry; but on being held to the fire, it will be of a yellowish green colour.

COLOURED FIRES.

RED FIRE.

ONE ounce and a half of dry nitrate of strontia, three drachms and six grains of powdered sulphur, one drachm and twelve grains of chlorate of potash, two drachms of the sulphuret of antimony, and one scruple of charcoal, will make a most beautiful and intense red fire. Pound the chlorate of potash and sulphuret of antimony each separately in a mortar, and afterwards mix them together on paper, then add them to the other ingredients. In mixing these ingredients it must always be remembered that chlorate of potash and sulphur explode when rubbed together.

GREEN FIRE.

For green fire, take twenty-seven parts of nitrate of baryta, thirteen of flowers of sulphur, five of nitrate of potass, three of charcoal, and two of metallic arsenic. Let the nitrate of baryta be well dried and powdered; pulverize the other ingredients completely, mix them carefully together, and then grind them with a muller on a stone slab, taking especial care to incorporate them thoroughly.

A BLUISH WHITE FIRE.

Take of nitrate of baryta twenty-seven parts by weight, of sulphur thirteen, of chloride of potassium five, of realgar two, and of charcoal three parts; incorporate them completely, and when inflamed they will emit that peculiar whitish-blue light accompanied by much smoke which is employed in fairy scenes at theatres.

BENGAL LIGHT.

Mix together sixteen parts of nitre, four of sulphur, and one o orpiment; place it on a tile, and apply a match: it will burn with bluish flame, and diffuse a most intense light.

ORANGE-COLOURED FIRE.

If some muriate of magnesia be mixed with a little alcohol, and then set on fire, a very beautiful orange-coloured flame will be produced.

SPUR FIRE.

This fire, the most beautiful of any composition yet known, is termed spur fire, from the sparks bearing a great resemblance to the rowel of a spur. It is generally made of saltpetre two pounds, sulphur one pound, and lamp-black three quarters of a pound, incorporated thoroughly together; it should then be put into cases about six inches in length, but not driven very hard. This composition is very difficult to mix. The saltpetre and brimstone must be first sifted together, then put into a marble mortar and the lamp-black added to them; incorporate the ingredients with a wooden pestle till the mixture appears of a dark grey colour; then drive some into a case for

trial, and fire it in a dark place; if the sparks, which are called stars or pinks, come out in clusters, and afterwards spread well without any other sparks, it is a sign of its being good; if any drossy sparks appear, and the stars are imperfect, the composition is not mixed enough; and if the pinks are very small and soon break, it is a sign that you have rubbed it too much. This fire has a better effect in a room than in the open air, and may be fired in a chamber without any danger; indeed, it is of so innocent a nature, that, although it seems an improper phrase, it may truly be termed a cold fire, for, if well mixed, the sparks will not burn a handkerchief when held in the midst of them; you may hold the cases in your hand while the fire jets out with as much safety as a candle; and if you put your hand within a foot of the case, you will feel the sparks fall like drops of rain.

CONCLUDING REMARKS.

Our limits warn us to close this highly interesting subject, and in so doing we shall observe that the experiments we have selected to elucidate the principles of chemistry are mostly very easy of attainment, and can be tried without incurring much expense; indeed the smallest quantities sold of some of the more expensive articles will be amply sufficient for the purpose of displaying their effects, whilst a trifling quantity, three or four pennyworths, for instance, of the more common ones will do, as the effects are as beautifully apparent in small as in large quantities. Neither is it necessary to purchase many glasses or vessels in which to make the mixtures, as some slips of common window glass will serve the purpose, if only a few drops of the liquids are mixed together. This economical plan has been adopted by Dr. Reid, of Edinburgh, with the greatest success, and tyros in chemistry would do well to bear in mind that Sir Humphry Davy taught himself with an apparatus which cost but a few shillings.

Fig. 35. Globules of sodium rolling down and burning on wet blotting-paper placed on an inclined board provided with ledges at the sides to prevent the metal rolling off.

OPTICAL EXPERIMENTS.

Fig. 36.

"Hail, holy LIGHT! Offspring of heaven, first-born,
. . . . . . Before the sun,
Before the heavens, thou wert: and at the voice
Of God, as with a mantle didst invest
The rising world of waters dark and deep."

MILTON.

"Oh, what a noble heavenly gift is light,
By light, that blessed being, all things live."

SCHILLER'S *William Tell.*

IT may be said without exaggeration that the chief facts in the science of chemistry have been discovered within the last eighty-five years, and a similar remark may be made with respect to the beautiful phenomena of light, viz., that the greatest refinements and improvements in the science of optics have been discovered and practised within about the same period, although, of course, much was effected and reduced to system at least 200 years ago. No other

branch of science has given larger scope for the exercise of the highest order of reasoning than the gorgeous and magnificent effects of light; and the study of its nature was pursued with the greatest diligence and success by the philosophers of antiquity. If the earth was always flooded with light, probably its nature would not have excited so much curiosity; but the very fact of its being the precursor of man's daily toil, the first greeting of each day, would induce a greater amount of thought to be devoted to its origin and existence; hence light was typified in various ways in heathen mythology, and Eos or Aurora was the name of the goddess of the dawn, who at the close of every night rose from her couch, and in a chariot drawn by swift horses ascended up to heaven to announce the coming light of the sun; whilst Helios or Sol, the god of the sun, was fancifully supposed to start in a chariot drawn by four horses from his magnificent palace in the east, to speed to his second royal abode in the west, where his horses fed upon herbs growing in the Islands of the Blessed. Such fanciful creations of imagination indicate that the thoughts of the ancients were turned to the consideration of invisible, imponderable light, and they endeavoured to give this "quintessence pure" a formal existence. The ancient Greeks were acquainted with the properties of the burning-glass, which was sold as a curiosity in the toy-shops, just as the kaleidoscopes and the magic lanterns are to be obtained in the bazaars at the present day. In order to comprehend the principles of these optical contrivances, it is necessary to speak of the nature of light, beginning with the enumeration of the sources from which it may be derived.

THE SOURCES OF LIGHT.

LIGHT emanates from (at least) six different sources. The first, the greatest and the grandest, is the sun, the centre of our planetary system, and the great source of light and heat to the earth. The magnificence of this celestial light-giving agent can only be appreciated by considering the gigantic size of the sun as compared with the earth, the former having a diameter of 770,800 geographical miles, and being 112 times greater than that of the earth.

The sun's volume is 1,407,124 times that of the earth, and 600 times greater than all the planets united. Sir John Herschel says, if a globe representing the sun, and two feet in diameter, be placed in the centre of a well-levelled field, and a circle described round it having a diameter of 430 feet, the representation of the earth placed on the circumference of this circle would not be larger than *a pea*, whilst the circumference would represent the orbit or path of the earth. Arago says, "It is no exaggeration to assert that the electric light is comparable to the solar light; the former is not effaced in the presence of that of the latter. According to the energy of the battery employed, the electric light varies from the fifth part to the fourth of that

f the sun; and, supposing it to be equivalent to about three or four thousand wax candles, the light of the sun, *at the surface of the earth,* would be equal to about twenty thousand candles on the same area as would be illuminated by a single electric light of great energy. Comparison is always a useful mode of instruction, and therefore it may be worth while to mention that the solar light is at least 300,000 times greater than that of the full moon; consequently the firmament must be gemmed with more than 300,000 full moons to produce a light equal to that of the sun. Light emanates from terrestrial matter, as when two substances are rubbed one against the other, and hence the use of the flint and steel; here minute particles of iron are rubbed off, the very act of friction being sufficient to produce the heat which helps their combustion in the air. Before the invention of the safety-lamp, and its use in coal mines, steel mills were in constant requisition in dangerous pits, and every coal hewer was provided with a little boy, whose monotonous duty consisted in turning a little steel wheel against a piece of flint, at the risk of continually rubbing off the skin from his fingers, or projecting the small particles of the flint or steel into his eyes; to say nothing of the occasional brutality of the coal hewer, who would allow no relaxation to the tired little fingers which helped to produce the light.

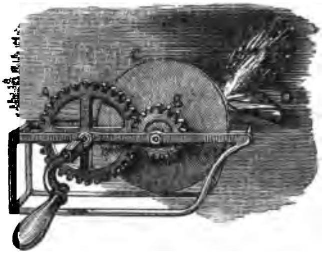

Fig. 37. Miner's steel mill. A B. Large and small cog wheels.
The cog wheel A has a handle attached. B. is on the same shaft that carries the steel wheel C.
The flint is shown at D.

Fig. 38. Miner at work in the coal mine by the light of the sparks from the steel mill.

The friction of a railway axle has occasionally been so great as even to set fire to the carriage to which it belonged.

Friction is, therefore, an important source of light, whether it be applied by civilized races to the ignition of a lucifer-match, or in the more troublesome and laborious efforts of a savage with his dried pieces of wood.

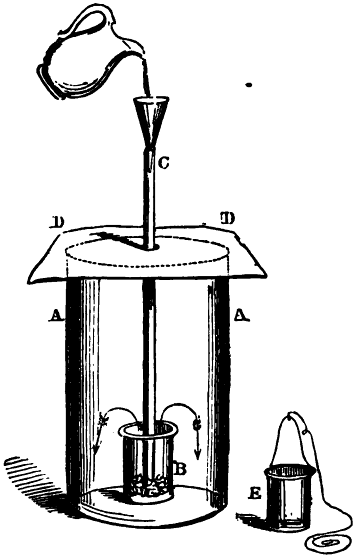

Fig. 39. A A. Large glass jar.
B. Small ditto, containing the chlorinated lime.
C. Tube and funnel, conveying the acid to B.
D D. Sheet of paper, with hole in centre to admit tube.
E. Small glass, used as a bucket.
The arrows show the direction of the heavy gas chlorine, and when sufficient is obtained, the Dutch metal may be dipped in.

A third source of light is chemical action; undoubtedly (next to the sun) the most valuable means of obtaining illuminating power without the exercise of physical strength. Light is procured from the mere contact of certain chemical agents. Thus, if some chlorinated lime, called chloride of lime, be moistened with water, and placed in a beaker glass standing at the bottom of a deep jar, and some acid be poured upon it by means of a tube and funnel, the acid being hydrochloric or sulphuric acid, effervescence takes place; a heavy gas, called chlorine, is disengaged, which falls to the bottom of the jar; and if a little Dutch metal, *i.e.*, copper leaf, is now dropped into it, light is produced by the sudden combination of the metal with the gas.

In performing this experiment great care must be taken not to inhale the chlorine gas, as it produces a most painful and irritating cough, which would last a considerable time. After performing the experiment, either place the glass on the chimney-hob till the gas has all passed up the chimney, or put it outside the window and shut down the sash; and after the acid has been poured in, put a plate over the top, to prevent any gas being carried out of the jar by accidental currents of air in the room.

A powder composed of chlorate of potash and sugar represents solidity. At the ordinary temperature of the atmosphere, these materials might remain in contact for years without evolving light, until touched with the smallest quantity (a drop) of oil of vitriol, when suddenly a little crackling noise is heard, a large flame

flashes upwards, and the heap of powder is gone—burnt up—changed into carbonic acid and aqueous vapour, which pass into the air; whilst a small quantity of a white matter, and, perhaps, a few specks of charcoal, remain behind. Before the extended manufacture and application of phosphorus in the preparation of lucifer-matches, the same mixture, combined with a small quantity of red lead and gum was attached to the ends of little bits of pine wood, and these, when dipped into a bottle containing asbestos moistened with oil of vitriol, immediately took fire as already explained.

A third, and excellent illustration of chemical action as a source of light, is shown in the combustion of all oil, tallow, wax, and gas in the production of artificial illumination; the perfection of the light depending, in a great measure, on the ignition of the solid charcoal, which introduces us to

The fourth mode of procuring light: viz., *by the increase of heat in solid bodies*, or what is called ignition in contradistinction to combustion, which means the actual burning of a substance.

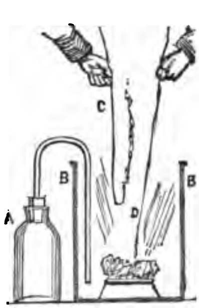

Fig. 40. A. Bottle containing marble and hydrochloric acid, generating carbonic acid gas, which passes by the bent tube into

B B. Large beaker glass, containing a little stand with gun cotton.

C. Taper extinguished by carbonic acid.

D. Ignited wire, which fires the gun cotton.

For instance, if a deep jar is filled with carbonic acid gas, and a piece of dry gun cotton is dropped into it, a flame, representing *combustion*, will not fire the cotton, as the lighted taper is extinguished before reaching the explosive substance, because carbonic acid gas extinguishes flame; but if a piece of iron wire be heated, *i.e.*, ignited, this may be passed through the carbonic acid gas unaltered, and, coming in contact with the gun cotton, immediately causes it to burn.

The increase of heat in solid bodies producing light is admirably illustrated in the dissection of the elements concerned in the combustion of ordinary gas, which consists chiefly of hydrogen gas and carbon; if the former is burnt, it combines with the oxygen of the air, water is formed, and much heat, but little or no light obtained. If, however, a coil of platinum wire is placed in the burning hydrogen, it becomes intensely ignited, and light is obtained; the metal is not consumed, or changed, or oxidized, only ignited, and if some powdered charcoal is substituted for the platinum wire and dusted in the flame, light is also obtained. To dust charcoal powder into a hydrogen flame would be a very tedious business, hence coal gas, which already contains the charcoal, supplies the element required, and being in excess, is not wholly and at once burnt up by union with the oxygen of the air, but is deposited in the body of the flame, where becoming ignited or incandescent, the light is produced, and this is the principle of the illuminating power of oil, tallow, wax, &c.

A fifth source of light, and one that may alarm or delight us according to the manner of its production, is Electricity. That wondrous power which man has rendered subservient to his command, and employs to convey his thoughts almost as quickly as they are conceived, by the electric telegraph. In many other ways, and especially as a light-giving agent, electricity promises in due time to become second only to the sun in utility and brilliancy.

On a dark stormy night there is nothing more awful (in consequence of the suddenness of the appearance and disappearance of the excessively brilliant light) than a flash of lightning. In vain do the nervous try to exclude the bright gleams of light by closing shutters or hiding heads under the bedclothes; the light has come and gone ere the words which chronicle its existence have escaped us, and by the time we have remarked "how blue the lightning is," the cause of the colour has vanished, the impression only remains upon the optic nerve.

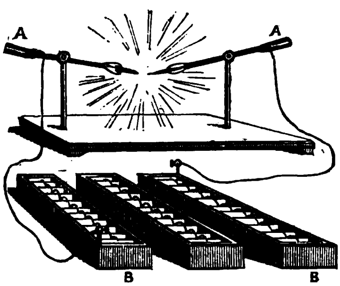

Fig. 41. A A. The universal discharge with charcoal points.
B B. Three batteries of ten cells each.

The electric light is obtained either by passing a stream of sparks from the prime conductor of an electrical machine, or by the use of a powerful voltaic battery of at least 30 pairs, on Professor Grove's principle, which must be conected with the charcoal points arranged on the ends of the instrument called the universal discharge.

The points must be constantly brought together, as the positive pole is always losing charcoal, which deposits partly on the negative pole; the carbon so deposited is not in a perfect state of aggregation, and soon burns away, otherwise the light is not caused by the combustion of the charcoal, and is produced by the ignition of the points, and the passage of the current of electricity from pole to pole.

The passage of the charcoal from one point to the other is perfectly and beautifully displayed on a screen to a number of persons at the same time, by using Duboscq's elegant arrangement, in which the electric lamp is placed inside a lantern with a plano-convex lens, and provided with a disc perforated with holes gradually decreasing in size. By adjusting the proper orifice to the lens, and connecting Duboscq's lamp with the battery of 30 cells, a picture of the charcoal points is projected on to the screen; the passage of the electric current (shown by a bluish light), with the transfer of the charcoal from the positive to the negative pole is very perfectly seen.

Professor Pepper's Duboscq cascade will long be remembered by the *habitués* of the Polytechnic.

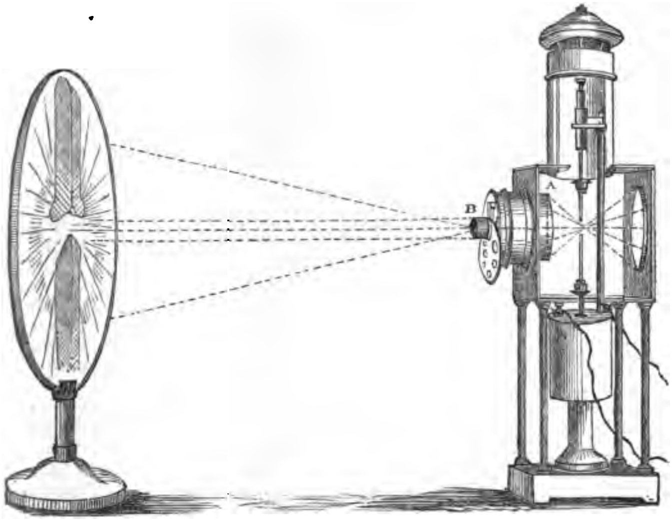

Fig. 42. Duboscq's Electric Lamp, Lantern, and Screen. The lamp is placed in the lantern, and the door removed, to show the inside.
A. The plano-convex lens.
B. The diaphragm, perforated with holes of various sizes.
The picture of the positive and negative poles is shown on the white paper screen facing the diaphragm.

The sixth source of light is perhaps more curious than all the others which have been enumerated, and is called "*Phosphorescence.*" This term must not be confounded with the use of the highly combustible substance called phosphorus, as the luminous effects are obtained from bodies which do not contain any of that element. Moreover, a phosphorescent light is evolved from living insects, and therefore it must (in this case) be the result of some remarkable organic process.

PHOSPHORESCENCE.

There are at least seven distinct means by which this kind of light is produced.

NO. I.—SOLAR PHOSPHORI.

Attention was first directed to this mode of causing bodies to shine in the dark by the experiments of a shoemaker of Bologna, who, being engaged in alchemical mysteries, had occasion to calcine some native sulphate of baryta, or what is commonly termed heavy spar, and he remarked that whenever this substance was exposed to the

sun's rays after being heated red-hot, it possessed the curious property of shining when taken into a darkened chamber. The shoemaker in looking for the philosopher's stone, missed the golden prize, but discovered this substance, which soon began to be in great demand amongst the curious under the name of Bolognian phosphorus, and after the death of Vincenzio Cascariolo, the clever shoemaker, a family of the name of Zagoni retained the secret of the preparation, and supplied the philosophers and dilettanti of Europe with this prepared substance.

Canton's phosphorus possesses similar properties, and is prepared by taking a dozen large oyster shells and placing them in an open fire for half-an-hour, after which the whitest and largest pieces are selected, mixed with about one-third of their weight of flowers of sulphur, pressed into a crucible with a closely luted cover, and heated red-hot for an hour. It should be remembered that the oyster shells alone, when heated for about an hour in contact with charcoal, *i.e.* placed in an open fire surrounded with coke, become luminous when exposed to the sun's rays, and emit curious prismatic colours in a darkened room.

Nitrate of lime, prepared by saturating nitric acid with lime from chalk, evaporating to dryness, and melting at a low red heat, evolves light in a dark room after exposure to the sun's rays.

The conditions of success in the use of these solar phosphori consist in a great measure in the warmth and dryness of the weather, as a cold or damp state of the atmosphere decreases the power of shining.

NO. II.—PHOSPHORESCENCE BY HEAT.

In this case it is only necessary to take various substances in the powdered state, and to sprinkle them on a heated surface, such as a platinum spoon, held over the flame of a spirit lamp, and an iron shovel, just red hot, taking care of course to perform the experiment in a dark room or a cupboard lined with black calico.

The powdered substances which become luminous in this manner are—

Fetid carbonate of lime called stinkstone, which is rather plentiful at Bristol.
Compact phosphate of lime.
Calcareous spar.
Heavy spar.
Powdered quartz.
Fluor or Derbyshire spar.

Mr. Pearsall has shown (in a very interesting series of experiments) that the luminosity of these substances is greatly increased by electrical discharges, and he found that it conferred the property upon many substances which did not otherwise possess it.

NO. III.—BODIES SPONTANEOUSLY PHOSPHORESCENT.

Various animal substances become luminous before putrescence has commenced, and especially the flesh of certain fish, of which the

most remarkable are tench, carp, sole; and herring, lobsters, and crabs, when perfectly fit for the table, will sometimes emit a phosphorescent light.

One of the most remarkable instances on record is that described by the late Mr. Daniel Cooper, and witnessed by the author, viz., the phosphorescence of the whole of the human bodies which were undergoing dissection at the Webb Street School of Medicine. The phosphorescence commenced in one of the subjects, and a portion transferred by a scalpel to the other dead bodies, conferred the same property upon them. The effect was extremely wonderful, not to say fearful; it reminded one of the ghostly story of "Frankenstein," and suggested the fanciful notion of the resuscitation of these poor remains of human mortality.

NO. IV.—PHOSPHORESCENT LIVING ANIMALS.

The glowworm (described with many other "Common Objects of the Country," by the Rev. J. C. Wood) is not a worm, but a beetle.

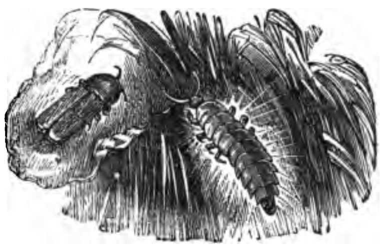
Fig. 43. Male and female glowworm.

The hundred-legged worm found in decayed poplar wood, or under lime, bricks, and pots in the garden, emits flashes of light when irritated by a little warm water. Whilst, in tropical climates, the Lantern and Firefly have been the theme of admiration of every traveller.

NO. V.—THE PHOSPHORESCENCE OF THE SEA.

Dr. Young and others are of opinion that it is caused by microscopic mollusks. "Every time," says the doctor, "I threw a net into the water I withdrew it full of biphores, beroës, and medusæ. In one single drop I discovered myriads of small beings moving rapidly about, and at every contraction of these animalculæ the emission of light became more intense . . . . I had placed in a glass vase some gigantic biphores; I saw them alternately rise and fall in the water, and all their movements were accompanied by a jet of fire, which increased the luminous intensity of the liquid fourfold."

The French Minister of Marine lately received a report from Captain Trébuchet, of the *Capricieuse* corvette, dated Amboyna, August 28th, 1860, in which he states that on the night of the 26th of that month, while tacking to reach Amboyna, lying at about twenty miles E.N.E., he and his crew witnessed the curious spectacle of the Milky Sea, which the Dutch call the Winter Sea, because both the sky and the waters present the appearance of fields covered with snow. The phenomenon lasted from seven P.M. until the return of daylight. They at first attributed it to the reflection of

the moon, then only three days old; but, as the appearance continued after the moon had set, this explanation had to be discarded. A bucketful of sea-water being drawn up and examined, it was found to contain about 200 groups of animalculæ of the same thickness (that of a hair), but of different lengths, varying between one and two-tenths of a millimetre, and adhering to each other by tens and twenties, like strings of beads. These insects emitted a fixed light similar to that of the firefly or glowworm, and it was admitted on all hands that the white appearance of the sea could only be attributed to these minute creatures, the numbers of which must therefore, exceed all imagination.

In a paper read before the Royal Society, written by Father Bourges, he speaks of the phosphorescence of the sea water in the wake of the ship, and says, "One day we took in our ship a fish, which some thought was a boneta; the inside of the mouth of this fish appeared in the night like a burning coal, so that, without any other light, I could read by it the same characters that I read by the *light* in the *wake of the ship*. Its mouth being full of a viscous matter, we rubbed a piece of wood with it, which immediately became all over luminous; but as soon as the moisture was dried up, the light was extinguished." This phosphorescent light may be one of the inscrutable wonders of creation, and serve possibly to illumine the eternal darkness of the great ocean depths to which the rays of the sun never penetrate, giving light to those animals which take their food near these valleys of the bed of the ocean.

NO. VI.—PHOSPHORESCENCE FROM VEGETABLE SUBSTANCES.

Decayed wood, and especially peat, has occasionally been observed to evolve a faint light, and even some flowers have been remarked to give out brilliant flashes of light during a warm summer's evening. The names of the flowers are the tuberose, nasturtium, and marigold; also the leaves of the phytolacca decandra, and certain mosses, with some species of rhizopherma, have been observed to be luminous in mines.

NO. VII.—EMISSION OF LIGHT DURING CRYSTALLIZATION.

Mr. H. Rose notices a remarkable instance of this property in the solution of vitreous arsenious acid in hydrochloric acid; one ounce of the arsenious acid should be dissolved in three ounces of the hydrochloric acid diluted with one ounce of water, and the whole boiled for fifteen minutes in a flask; when very slowly cooled the arsenious acid gradually crystallizes, and nearly every crystal as it forms emits a bright flash of light in a darkened room.

The cause of phosphorescence does not yet seem to be perfectly understood; by the vibratory, or undulatory theory of light, it is possible to conceive that vibrations may be commenced in phosphorescent bodies, and communicated to the surrounding ether. The glowworm and firefly may be naturally endowed with the power to produce these rapid vibrations, the principle being, that as vibra-

tions of the air produce sound, so the vibrations of the theoretical ether, which is supposed to fill all space, would generate light.

Phosphorescence is quite independent of combustion; it may arise in some cases from electrical disturbance, but taking it as a whole, scientific men are obliged to confess their ignorance of the causes which produce the leading cases of phosphorescence already enumerated.

PHENOMENA OF LIGHT.

HITHERTO the experiments and remarks in this article have applied merely to self-luminous bodies, but yet we see every other shape and form on the surface of the globe, although the bodies may not be self-luminous. The cause is very simple, and depends chiefly on the property possessed by all bodies of reflecting or throwing off the rays of light.

For instance, we might enter in imagination the cavern of the Forty Thieves in the tale of Ali Baba; the countless riches are comparatively useless, because we cannot see them, they do not shine and make themselves apparent in the dark; but a lighted taper or torch very soon throws its rays in every direction, and these falling on the surrounding objects are reflected to the eye and there produce the phenomena of vision.

A bright beam of light may be passed from the Duboscq lantern across a darkened chamber, and if it falls upon a piece of black velvet and the face is turned away from it, hardly any light is perceptible in the room; but if the rays be received on a sheet of cardboard, then the secondary reflection illumines the room. It is this reflection of light by clouds and masses of vapour that produces the diffused light of day. If the globe was not surrounded by an atmosphere, the sun would look like a huge electric light in a perfectly black sky. Hence the important connexion between luminous and non-luminous bodies. For the purpose of reasoning on the properties of light, it is usual to consider a beam of light as made up of rays, and when a ray of light remains in the same medium of the same density, it pursues a perfectly straight line, but if it passes out of that medium into another of a different density, or into any other solid, fluid, or gaseous body, it may be disposed of in four different ways. It may be

1. Reflected.
2. Refracted.
3. Polarized.
4. Absorbed.

The limits of this very popular article will not allow us to discuss Nos. 3 and 4, but there are many entertaining experiments to be performed with light in the use of various reflecting and refracting substances.

THE REFLECTION OF LIGHT.

Nature supplies us with bodies of all degrees of reflecting power, and it is a property which is influenced rather by the condition of the

surface than the nature of the material, as we may destroy the brilliancy of a bright mirror by breathing upon it, and we may also confer a reflecting surface on black charcoal by applying the thinnest film of gold or silver leaf.

Concave mirrors, in which the surface corresponds with the inside of a watch-glass, have the property of collecting the rays of light, whilst convex mirrors, in which the surface resembles the exterior of a watch-glass, scatter the rays in all directions. Flat surfaces afford plain reflections, and one of the prettiest applications of flat-reflecting surfaces is shown in that beautiful invention of Sir David Brewster called

THE KALEIDOSCOPE.

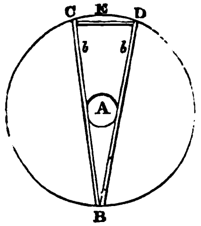

Fig. 44.

This interesting instrument is of modern invention, and forms a toy of the most pleasing kind. Rough, though effective, kaleidoscopes may be purchased for a very moderate price at most toy-shops, but for the instruction of those of our readers who would like to make them, we proceed to give some instructions by which they may construct very passable specimens for a trifling expense. Get a tube of tin or pasteboard of eight or ten inches in length and one and a half or two inches in diameter; have one end stopped up with a piece of tin firmly soldered in, and let there be a slight hole made exactly in the centre of this end piece. Next procure two pieces of looking-glass of nearly the length of the tube, for reflectors; but if looking-glass is not easily obtained, strips of good new crown glass will answer the purpose, if the lower surfaces are blackened with lamp-black or black wax. These plates of glass must be put into the tube in the manner shown at B C B D in the marginal figure; they must be quite parallel and close to each other at the lower part B, and kept asunder at the upper part by a piece of cork or any other substance E; the polished sides of the glasses must be uppermost, as at *b b;* A indicates the sight-hole at the farther end, and close to this the reflectors must be fitted. The reflectors being put in, a piece of glass of the same diameter as the tube, is to be pushed into the tube so as to touch the reflectors, sundry bits of different coloured glass are to be laid on it, and a ring of brass or copper placed round its edge, and then another piece of glass, one side of which has been ground with fine emery, laid upon that; the edges of the tin tube are then to be burnished down round the last mentioned piece of glass, by which plan the glasses are firmly secured in their places and the instrument completed. If a piece of marbled or tinted paper is afterwards nicely pasted over it, the kaleidoscope will look very neat and workmanlike.

THE MYRIAMOSCOPE, OR MAGIC DESIGNER.

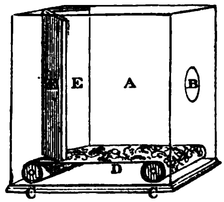

Fig. 45.

This instrument is a variation of the Kaleidoscope, possessing much of the beautiful effect of that pleasing invention, without its liability to be affected by a shake, so as to derange the elegant forms which it produces. A is a square box, in the front of which the sight-hole B is made ; two rollers, C C, are placed at the bottom of the box, and in order that they may be made to move round with facility, knobs or handles should be fixed to the ends of their axles at the sides of the box. On these rollers a piece of calico D, must be wound, and upon which fanciful borders, flowers, and ornaments cut out from pieces of paperhangings, must be pasted. Two plane mirrors E E joined together by a strip of leather, hinge-fashion, are then to be put on the calico, as shown in the margin, and, of course, all the objects thereon make a very pretty display in the glasses when viewed through the sight-hole B. The mirrors must be so constructed that they may be put to any inclination by means of two small pieces of wood fastened to them, and passing through the sides of the box. An opening should be made in the box for the convenience of renewing the subjects, and the top of it be covered with muslin, strained tight, or some other semi-transparent medium.

THE REFRACTION OF LIGHT.

Light is refracted, or bent out of its course, when it passes obliquely through a medium of greater density than that which it has been traversing, so as to fall quite in a different place to what it would have done, had it not passed into that medium ; and the amount of this refraction or bending of the light is always governed by its obliquity, and the nature of the substance through which it progresses. There are some substances or media which are of greater density, and refract light better than others, as for instance, alcohol refracts it more than water, oil more than alcohol, and glass even more than oil. Amongst the many useful inventions which the progress of civilization and knowledge has brought forward, there are few which are of so much utility as those which depend upon the refractive powers of glass for their effect ; and these are the telescope, microscope, camera obscura, magic lantern, &c. &c. The pieces of glass used in these instruments are termed *lenses*, from their being made in the shape of a flat bean or lentil ; this shape, from being rounded outwards on both sides forms what is called a convex lens, and in addition, the concave, or *hollow* on both sides, with the various modifications of both kinds of lenses are employed for optical purposes. The convex lenses cause the different rays which pass through them from any given point or object, to bend and unite together again at another point beyond them. The more

convex the lens is, the nearer is its focus, for it has been ascertained that the focus of a double convex lens is exactly where the centre of the sphere would be, of which the surface of the lens is a portion; consequently, in proportion to the convexity of the lens, so will the nearness of its focus be, as it then forms a part of a smaller sphere. When the light proceeding from all points of any object placed before a lens is collected at a certaint point beyond it, and received on a white screen or other medium in a darkened room, it produces the well-known effects of the magic lantern, the solar and oxy-hydrogen microscopes, and the camera obscura; and when the image beyond a lens is viewed in the air, in a particular direction, it then shows the disposition of parts which form the telescope, common microscope, &c. The concave lens acts exactly the reverse of the convex, that is, instead of converging the rays to a point, it expands them, and causes them to fill a space considerably larger than the size of the lens itself.

Some of the most striking of celestial appearances, and which are of very frequent occurrence, are the result of the reflection and refraction of the rays of light. The serene mild glow of twilight, which so softly and sweetly ends the day, and diminishes the transition from the burning glare of the sun to the cold hues of night, is owing to reflection, and so also is that beautiful many-coloured arch, the rainbow. The varied tints of the clouds, from the grey, pearly, morning dawn, to the brilliant crimson and gold glories of sunset, are produced by a combination of causes, absorption, reflection, and refraction. The deceitful Mirage is another effect owing to refraction. It is occasioned by unequal refraction, that is, when the rays of light enter a medium of different densities, and is a phenomenon of rare occurrence in temperate climates, occurring chiefly in those subject to the extremes of temperature, whether of heat or cold. In the arid deserts of Africa, the mirage frequently presents the appearance of a delightful tract of country stretching across the wide plain, in which the traveller fancies he may refresh himself and his camels, sheltered by lofty palm-trees, from the scorching rays of the sun; but as the wanderer pursues his onward course, he finds the unsubstantial forms vanish before his eager gaze, making the dreary way still more desolate from the bitterness of disappointment. In the Arctic regions also, the mirage presents forms of great interest and beauty, but of a different character from those in the torrid zone, displaying lofty towers and pinnacles, high battlemented walls and aërial palaces, from the refracted forms of the icebergs. There are many pleasing ways of showing the principles of refraction.

EXPERIMENTS ON REFRACTION OF LIGHT.

Put a piece of money at the bottom of an empty basin, and then retire a few steps backwards, till the edge of the basin screens the money from your sight. Keep your head steady, and request some one to fill the basin very gently with water; as the water rises the

coin will come gradually into view, and when the basin is nearly full of water it will be completely visible.

By the assistance of the Duboscq lantern, arranged as already described, with the exception of the diaphragm, which must be removed and a piece of thick cardboard or brass cut in the form of an arrow arranged in its place, and a double convex lens placed in front, a perfect image of the arrow is thrown on the disc, and whilst the picture is visible, if a piece of plate-glass, marked D in the cut, say one inch wide and half-an-inch thick and six inches long is held across the shaft of the cardboard arrow, a piece of the shaft is seen to be broken out or refracted, as shown in the picture below.

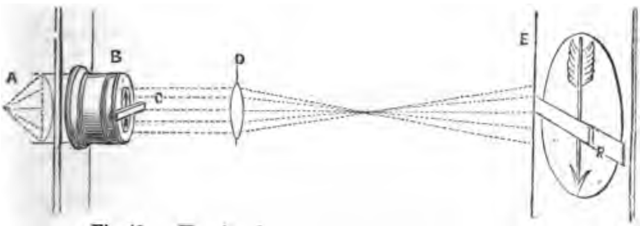

Fig. 46. A. The electric, or oxy-hydrogen light.
B. The plano-convex lens, or "bull's-eye."
C. The bit of plate glass, *the refracting medium*, in front of the arrow.
D. The second double convex lens.
E. The image on the screen, showing the arrow-shaft broken, or refracted, at R.

THE MAGIC LANTERN.

The MAGIC LANTERN, one of the most amusing of optical instruments, was invented by Kircher, about the middle of the seventeenth century, and was of the greatest service to the magicians of those times, enabling them to work upon the credulity of the ignorant and superstitious with the utmost facility. As a vehicle of amusement, it contributes in no small degree, in the shape of a galantee show, to the hilarity of a party of merry younkers in a long winter's night; and as a means by which lectures on astronomy can be elucidated, it arrests the attention of the old and wise.

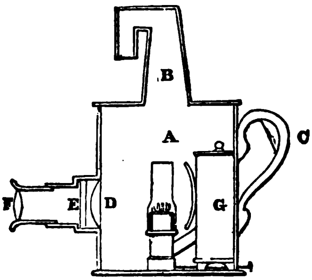

Fig. 47.

The instrument, the construction of which demands our attention first, is represented in the margin. A, is a box made of wood or tin, about eight inches square, having a bent funnel or chimney, B,

at the top; a handle, C, renders it a portable instrument, and holes are made near the bottom to feed the flame of the lamp with the air which is requisite for its combustion; in the front of the box there is a tin tube, furnished at the end near the light with a plano-convex lens, D,—which indeed is affixed to the lantern itself,—and at the other, a doubly convex lens, F; this tin tube is fixed to the lantern by a square foot, the sides of which are open, as at E, to admit the sliders, and the end of the tube in which the doubly convex lens is fastened is made to slide in and out for convenience when adjusting the focus; a third lens is occasionally employed when the space is very confined, as a larger field of view can be obtained by its aid than in the ordinary method. The lamp, G, is a common argand burner, furnished with a concave tin reflector, to concentrate the intensity of the light; and if the lamp is made to slide backwards and forwards by means of a wire, it will be so much the more useful.

The Phantasmagorial Lantern varies but slightly from the foregoing, the chief points in which it differs being in the form of the tube containing the doubly convex lens, which is made to project more beyond the lens, F, and in the lens itself being contrived so as to move readily backwards and forwards, either by a rack and pinion, or studs fastened on each side; in a flap to shut off the light abruptly, which may be either a tin slider to run into the groove, or else a piece of tin fastened in the front of all; and in the top of the square chamber, in which the sliders run, being made so as to open on occasion.

PAINTING THE SLIDERS.

The sliders are made of pieces of glass, surrounded by a slight frame, and in dimensions are of course regulated by the depth of the aperture intended for them in the lantern. Few hints can be given, beyond naming the colours, and the mode of preparing them, towards the painting of the sliders, as taste is the best guide, and practice the most impressive instructor in all matters relating to painting. The colours proper are only such as are transparent, and they are the following:—Gamboge, scarlet lake, Prussian blue, a green made of distilled verdigris and a quarter of its bulk of gamboge, burnt sienna, burnt umber, and lamp-black. A few materials, such as a glass muller, and slab, which last may be about six inches square; a palette-knife, and some small bottles to put the colours in after they are ground, are also requisite. The colours should be ground up with Canada balsam and turpentine, equal parts of each, or if in that proportion they are too thick for grinding freely, rather more turpentine may be added; so mixed they require about a week to dry, and have a very beautiful appearance; but if it is wished to have them harden in less time than that, mastic varnish may be employed instead. When painting, take a very little colour at a time out of the bottles, as it soon hardens; and if too thick, temper it with turpentine. A piece of glass will serve as a palette, and a bit of stick as a means of getting the colour out of the bottles. The

black pigment used in darkening the surface of the glass round the figures of the Phantasmagorial sliders, is composed of lamp-black and asphaltum, dissolved in turpentine.

The subjects intended for the sliders must be carefully drawn upon a piece of paper, which should be placed under the glass, and then painted from, and too much attention cannot be paid to the drawing of them, for when they are thrown upon the wall, all their defects, however minute, are enlarged to an astonishing extent.

Those parts of the subjects which are to appear white, must be left entirely destitute of colour, as flake, and all other whites, are opaque pigments. The mixed colours are produced by blending the colours before-mentioned; thus greens are made by means of yellow and blue, orange by yellow and carmine, &c.; this last, although not an exact orange, is near enough for the purpose, for the red which composes the proper tint, is opaque, and consequently useless. The shadows may be obtained either by stronger tints of the same colours, or by shades of brown or blue as may be requisite. It is necessary to observe that the sky tints must be darker than they are intended to appear, for the yellow light of the lamp throwing a yellowish tone upon the colours, they would lose their effect were they not so managed; for the same reason, the green of trees and grass should be painted of a bluish green, the reds be but very slightly used, and never shaded with blue; and purples should also be but sparingly employed, for the yellow tone of the lights uniting with the blue and lake colours used in the purple, forms a decidedly neutral tint, or blackish purple, much too dark and unintelligible for the purpose. As it is often necessary to remove some parts which do not harmonize, even after they have well dried, a penknife will be found of great assistance, and when bright lines are required upon a dark ground, the effect is easily managed by scratching the colour away with a needle or any other pointed instrument; and if the lines are to appear faintly coloured, it is only necessary to paint them delicately after the scratching is completed.

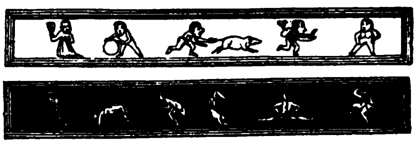

Fig .48.

The sliders for the common magic lantern are transparent, that is, the figures are painted on a piece of plain glass, whilst on those used in the phantasmagorial lantern the figures are surrounded by an opaque black tint, as in the illustrations; the figures on the former are usually shown upon a wall, as represented in the headpiece to this chapter, page 53, and invariably have a circle of light around them; whilst those in the latter are thrown upon a semi-transparent screen, which is placed between the spectators and the lantern, and in consequence of no circle of light accompanying them, have a very beautiful appearance.

Almost magical effects of light, shade, and motion, may be pro-

duced by means of different glasses ; and the sliders so adapted are termed "moveable sliders."

Landscape glasses are glasses on which several views are painted, divided from each other by some slight foreground object, as a tree, or a building, or guidepost. Various effects, from the brightest mid-day to the deepest tints of night, may be produced in these, by means of double sliders, and these contrivances may be thus applied. Cut away the frame of the slider at each end, nearly even with the glass, and fasten two narrow strips of wood along the glass, one at the top and the other at the bottom; the piece of glass which is to be moved, should exactly fit the space between the upper and under frames, and act upon the slips, and to keep it steady in its place, two or three pins may be driven into the slips.


Fig. 49.

Storm glasses, which are very ingenious representations of the effects developed by a change from a calm to a thunderstorm, require two glasses, as in the former slider: No. 1 in the annexed illustration shows a common slider painted at one end to represent a calm of sea and sky, and the sun setting in splendour; towards the centre the clouds appear threatening, and a gentle undulation of the water breaks its repose; farther on a still greater agitation of the clouds and water is shown; and at the other end, the lightnings flash, and the sweeping wave tells of the war of elements. The effect is materially heightened by means of the second slider, No. 2, having several ships painted on it, and these, of course, must correspond to the action of the water, from the bark sailing in quiet majesty to the tempest-torn and shattered hulk.

The effects of moonlight and sunrise may also be imitated by double sliders, and by a third one, figures may be introduced upon the scenes to add to their beauty.

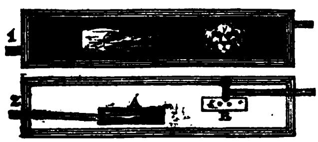
Fig. 50.

The eyes and mouths of figures and animals may be made to move, and produce a most singular, nay almost frightful effect, and by referring to the marginal illustration, the modes by which these are managed will be clearly understood. In No. 1 the heads of a crocodile and lion are delineated, and in No. 2 the contrivances for moving the jaw of the one and the eyes of the other. A, represents a piece of talc having the lower jaw painted upon it and surrounded with black, which fills up a space of corresponding size left blank in the perfect slider; a slight lever should be fastened to this piece of talc, act upon a pivot on the frame, and project a little beyond it; and as it moves up and down, so will the crocodile's mouth appear to open and shut. The eyes of the lion must be painted black upon a transparent piece of talc, as at

B, from which a side lever should be carried, as in the former case, to a little beyond the frame, and to prevent the talc from shifting too far either backwards or forwards, a drop or two of sealing-wax, or a little knob of wood fastened to the glass on each side, either of the talc or lever, will be found sufficient.

SCREENS FOR THE LANTERNS.

As we before briefly stated that different media were required, on which to show the effects of the Magic Lantern and Phantasmagoria, we must, in concluding this article, give some directions respecting them. Although any white surface will do very well to receive the objects from the Magic Lantern, yet a clean sheet stretched tightly upon a wall, is by far the best, as the chief point is to have a medium of perfect whiteness and quite flat. The screen for the Phantasmagoria may be made of tissue paper strained upon a frame. Some persons recommend oiled paper as the best medium; but in our opinion, paper so prepared is too transparent, the plain tissue being thin and translucent enough for any purpose.

Wetted muslin and waxed muslin are also advocated by some persons; but for a screen suited to the pockets of young experimentalists, nothing can be better than the one we recommend.

THE STANHOPE LENS

Is a very simple, portable, and economical species of microscope, invented by the late Earl of Stanhope. It is a cylinder of glass, about half an inch in length, and a quarter of an inch in diameter, and is generally mounted in white metal, silver, or gold. Both ends are ground convex, one rather more so than the other, and as its focus does not exceed its length, it is only necessary to put the object to be viewed either upon or in immediate contact with the end which has the slighter degree of convexity, to hold the instrument up to the light and look through it, when the object will be seen considerably magnified, to the extent, we believe, of 4096 times; its magnifying power is therefore nearly equal to that of many compound microscopes. The animalculæ in stagnant water, the mites in cheese, the farina and delicate leaves of flowers, the beautiful down upon the wings of butterflies and moths, human hair, and hairs of different animals, are amongst the objects which this lens developes in a lucid manner, as likewise the exquisitely minute crystallization of salts, if a drop of a solution of salts be lightly spread over one end of it, and viewed instantaneously ere the moisture fully evaporates.

Fig. 51.

THE CAMERA OBSCURA.

Have a box made about twelve inches in length, four in depth, and six in width; in the middle of one end of it let a hole be bored, as at A, in the annexed diagram, in which put a doubly convex lens; and at the other end, inside the box, place a piece of good looking-glass,

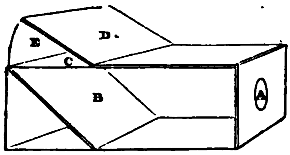

Fig. 52.

as at B, inclining it at an angle of 45°, or in less technical phrase, in a position midway between the horizontal and perpendicular, so as to reflect objects upwards. Part of the top of the box must be made so as to act the part of a lid, upon hinges, as D, and the space beneath be filled up by a piece of ground glass C, upon which medium the objects are reflected from the looking-glass with the utmost exactness and greatest beauty, so as to appear like an exquisite picture in miniature. Sides are usually added to the lid, as at E, to keep off as much of the circumambient light as possible. In some cameras, instead of a fixed lens, a sliding tube, with a lens at the extremity, is employed. The inside of the box should be painted over with lamp-black, or in default of that, stained with ink.

SIMPLE MICROSCOPES.

Get a piece of thin platinum wire, and twist it round the point of a pin, so as to make a very small ring with a handle to it. Next break a piece of flint glass into pieces about the size of mustard-seeds, or somewhat larger; put one of the pieces upon the ring of wire, and hold it in the point of the flame of a candle; when the glass melts, it will become of a completely globular form, and serve, when mounted, every purpose to which microscopes can be applied. The simplest mode of mounting these diminutive lenses, is either to put one between two pieces of brass, which have holes made in them of just the size to retain the edge of the lens, or they may be fastened to a single piece of brass by the aid of a little gum. It is to be observed, that the smaller the drop of glass, the more globular it will remain, and consequently possess greater magnifying powers.

WATER LENSES.

Temporary microscopes of considerable distinctness may be very easily made, by piercing a hole about the size of a pin's head in a piece of brass, and carefully placing a minute drop of water on the hole, where it will assume a globular shape. These lenses, as may be imagined, are very easily rendered useless, being affected by the slightest movements.

THE PRISMATIC COLOURS.

Our young readers will find these three experiments upon the colours in a ray of light of great interest and beauty.

Close the shutters of a room into which the sun is shining, and so exchange midnight gloom for meridian brightness; and if there is not an aperture in the shutters, then bore a little one. Hold a prism at a short distance from the aperture, so as to allow the slender stream of sunlight to pass through, and be decomposed by it; when instead

of a little round spot on the opposite wall of the room, an oblong image will be displayed, consisting of the seven colours of the rainbow, red, orange, yellow, green, blue, indigo, and violet. This image is called the solar spectrum.

If the hole in the shutter is exceedingly small, and no prism is employed, then only four colours are evident, and these are red, green, yellow, and violet.

The above experiments show by decomposition, that light is of a compound nature; and to confirm them, it is only necessary to recompose the seven colours, and produce the pure sunlight effect, as follows :—

Take another prism corresponding in every respect with the first, and placing them both together, so as to form a parallelogram, the seven rays will be reunited, and form a single spot of light.

In concluding this brief sketch of the nature and properties of light, it will be as well to notice the structure of the human eye, the organ by which the glorious works of the all-wise Creator are observed and impressed upon our minds. The human eye is formed, externally, by a hard membrane termed the *sclerotic coat,* or commonly the *white of the eye;* in the forepart of this coat, there is an opening called the *cornea,* from its resemblance in texture to polished horn; the interior of the eye is lined with a fine membrane, the *choroid,* which round the cornea is fringed by the *ciliary processes,* behind the *iris;* through the centre of the latter, or the *pupil,* the rays of light pass into the chamber of the eye. The *crystalline humour* or lens, which is in form like a doubly convex lens, is situated among the ciliary processes, and is the immediate instrument of vision, as it conveys the light from the pupil to a focus at the back of the eye. A delicate membrane called the *retina,* which is an expansion of the optic nerve, lines the back of the eye, and receives the images of every object from the crystalline lens, in most exquisite perfection, and most exact proportion. There are two humours for preserving the globular shape of the eye, the *aqueous* and the *vitreous;* the aqueous, as its name implies, is perfectly limpid, and is before the lens, immediately under the cornea; the vitreous fills the large cavity of the eye, to which it gives the globe-like form, and receives its appellation from being enclosed in a transparent spongy structure, so as to resemble, in some degree, molten glass.

The eye is in effect a camera obscura, in which the refracted light gives a very small but brilliant representation of external objects.

OPTICAL AUGMENTATION.

Take a large conical-shaped drinking-glass, and put a shilling into it, and fill it about half full with water. Put a plate upon the top of the glass, and turn it very quickly over, so that the water may not escape, and a piece of silver as large as half-a-crown will immediately appear in the plate, and some little way up the glass another piece will present itself, about the size of a shilling. This effect is caused by refraction.

THE THAUMATROPE, OR WONDER TURNER.

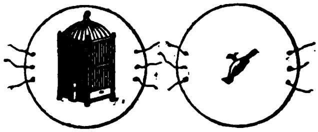

Fig. 53.

The Thaumatrope is an exceedingly amusing toy of very simple construction and pleasing effect. It is made in the following manner:—cut out a circular piece of card-board, and affix to it six pieces of string, three on each side, as delineated in the margin. Paint on one side of the card a bird, and on the other a cage, being particularly careful to draw them upside down to each other, otherwise the desired effect will not be produced. When showing the toy, take hold of the centre strings between the forefingers and thumb of each hand, close to the card, and twist or twirl the card rapidly round, and lo! the bird will appear snugly ensconced in its cage. The principle on which this pleasing toy acts, is, that the image of any object received on the retina or optic nerve, which is at the back of the eye, is retained in the eye for about eight seconds after the object causing the impression is withdrawn; consequently the impression of the painting on one side of the card is not obliterated ere the painting on the other side is brought before the eye, and it therefore follows that both sides are seen at once. The subjects suited to the Thaumatrope are very varied; amongst others, the following are well calculated for display; a juggler throwing up two balls may be drawn on one side of a card, and two balls only on the other, and according to the pairs of strings employed, he will seem to toss two, three, or four balls, the body and legs of a man on one side, and his head and arms on the other; a candle and its flame; a mouse and a trap; and a horse and his rider; this last is a very good one, as by using the different pairs of strings, the relative positions of man and horse may be varied most singularly.

THE STROBOSCOPE, OR PHENAKISTISCOPE.

This is a most amusing instrument, and its principle resembles the thaumatrope, its effect depending, like that, upon the continuance of the image of an object upon the retina. It consists of a disc made of stout cardboard, upon which, towards the edge a series of figures in eight or ten different positions is painted; thus if it be wished to produce the illusion of a man running, the first position should be quiescent, standing upright, the second advancing forward a little, the third stepping out still more, and so on to the sixth figure, which should be drawn as if running at full speed; the remaining attitudes should show the person gradually returning to the first quiet attitude.

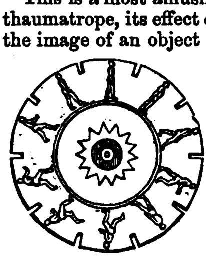

Fig. 54.

Between each figure a slit must be made about three quarters of an inch in length, and a quarter, or less, in width, running in a parallel direction with the radii of the disc, and extending to an equal distance from the centre, as in the illustration. This disc when completed should be put upon a handle as in the annexed figure. No. 1. shows a little nut, which must be unscrewed ere the disc can be placed on its axis, and which keeps it in its proper place, so that it cannot lean forward and spoil the experiment; 2 is the disc, and 3 is a nut fixed to the axis by which the rotatory motion is given to the disc. When trying the effect of this instrument, stand before a looking-glass, and hold the painted face of the machine towards the glass; cause it to revolve on its axis, and look through the slits, when instead of beholding a mass of confusion, as might naturally be expected, and as would undoubtedly be the case were the disc viewed in the ordinary way, the figures will seem to be running as fast as possible, and with very natural movements, their velocity being of course proportioned to the rate at which the disc is impelled. The number of subjects adapted for this species of exhibition is considerable, and if they are well drawn they may be made the source of much merriment. Especial care must be taken, when drawing them, to make the figures correspond exactly with each other in shape and depth of tone, as much of the good effect of the display depends upon their accuracy in these particulars.

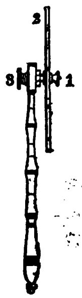

Fig. 55.

OPTICAL DECEPTIONS.

Faraday has shown that if two equal cog-wheels be cut out of cardboard, placed upon a pin, and turned round with equal velocity in opposite directions, instead of producing a hazy tint, as one wheel would do, or even as the two would if revolving in the same direction, there is presented an extraordinary appearance of a fixed wheel. Again, if one moves somewhat faster than the other, then the spectral wheel appears to move slowly round; if the cogs be cut slantwise on both wheels, the spectral wheel, in like manner, exhibits slant cogs; but if one of the wheels be turned so that the cogs shall point in opposite directions, then the spectral wheel has straight cogs. If wheels with radii or arms be viewed when moving, then similar optical deceptions appear; and though the wheels move ever so fast, yet the magic of a fixed wheel will be presented, provided they move with equal velocities. If they overlap each other in a small degree, then very curious lines will be seen.

Perhaps the most striking deception is the following:—a pasteboard-wheel has a certain number of teeth or cogs at its edges; a little nearer the centre is a series of apertures resembling the cogs in arrangement, but not the same in number; and still nearer the centre, is another series of apertures, different in number, and vary-

[illegible] new arrangements

[illegible] to its appear[illegible]
[illegible] opposite direction
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[illegible] of blue silk [illegible]
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ELECTRICITY, GALVANISM, AND MAGNETISM.

Fig. 56. The Origin of Galvanism (page 78).

THE primary object of the very elementary scientific articles in this work is to excite *curiosity* in the youthful mind, so as to induce a desire to read and study more extended and complete works on the various subjects to which they relate. The vast increase of knowledge derived from actual experiments with electricity, magnetism, and electro-magnetism precludes the idea of giving a complete description of all the varied phenomena in these branches of the science; brevity and simplicity have therefore been specially studied in the following experiments, which may be very appropriately prefaced with a glance at the historical connexions of these imponderable agents.

xact nature of ELECTRICITY has not been ascertained, but i ered a highly subtle and elastic fluid. Its name is deri Greek word *electron*, signifying amber, on which substa its effects were first observed. The name of the perso

[illegible] when
[illegible] down
[illegible] at
[illegible] and
[illegible]

[illegible] over their surfaces
[illegible] wool, hair,
[illegible] called non-co-
[illegible] which accumu-
[illegible] media [illegible]
[illegible] Its effects
[illegible] clouds, and
[illegible]
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[illegible] continued

[illegible]

posterity. It is proper to state that this somewhat romantic story is denied by some historians of the science.

The uses of galvanic or voltaic electricity for scientific purposes are calculable, and its phenomena are so various and extraordinary, as render the study of this science exceedingly interesting. By means of a galvanic battery substances are decomposed, colours changed, water is decomposed, and motion is given to lifeless bodies.

The experiments we give on galvanism show the effect of the combination which forms what is called a simple galvanic circle, by means of two metals, zinc and silver, or zinc and copper, and water mixed with sulphuric acid.

Galvanic action is always accompanied by chemical action, and all that is necessary to disturb the galvanic or voltaic electricity, is to unite two metals together, and subject them to the action of a fluid which will act chemically upon one of them more powerfully than upon the other.

A galvanic circle may also be formed of one metal and two fluids which have a different action upon the metal employed.

MAGNETISM is probably some modification of electricity; at least there is sufficient evidence that these causes are intimately connected, if not identical, but philosophers are as yet ignorant of its nature. It is equally unknown the exact time when, and the country where, the property of the magnet was first considered. The Greeks of the time of Pythagoras were acquainted with its property of attracting metals. It was also familiar to the Arabs and the Indians, and the Chinese from the earliest ages have known its polarity or directive power, the needle being employed amongst them 1000 years before Christ to direct travellers by land. In Europe, a Neapolitan, named Flavio Gioia, who lived in the thirteenth century, has been regarded by many as the inventor of the mariner's compass; but it was in use in the eleventh century in Iceland, as is confirmed by the historian Arc Frode, who wrote, about that time, the history of the discovery of his country, and who speaks of the mariner's compass in very definite terms, and thus indirectly shows that it was employed or invented nearly as early as the tenth century.

The property designated by the word magnetism is found in an iron ore of a certain composition, and of a dark grey colour and peculiar lustre. This ore alone is the natural local habitation of magnetism, whilst others are subject to its influence, or attracted by it.

This singular property of the loadstone is imparted to iron and steel by rubbing and keeping them close together for some length of time. The steel retains the magnetic principle permanently; but iron loses the power as soon as it is separated from the magnet. The steel thus prepared acquires the same directive and attractive power as the loadstone or natural magnet, and is employed for purposes of the utmost importance.

proceed to give the youthful amateur the opportunity of ing the principles of electricity, galvanism, and magneti al interesting and simple experiments.

SIMPLE MEANS OF PRODUCING ELECTRICITY.

To show the nature of electrical action, rub a piece of sealing-wax or amber upon the coat-sleeve, and it will be found that while warm by the friction it attracts light bodies, such as straws or small pieces of paper. If a clean glass tube be rubbed several times through a silken or leather cloth, and presented to any small substances, it will immediately attract or repel them; and if a poker suspended by a dry silk string be presented to its upper end, then the lower end of the poker will exhibit the same phenomena as the tube itself, which shows that the electrical fluid passes through the metal. But if for a metallic body a stick of glass or sealing-wax be substituted, these phenomena will not occur, which proves that the electrical fluid does not pass through these substances.

Fig. 57.

By this it will be perceived that besides the class of bodies called electrics, there is another which we call conductors. These bodies cannot be excited themselves, but have the power of transmitting the electric fluid through them. These bodies comprise all the metals, some metal and metallic ores; the fluids of animal bodies, water, and other fluids, except oil, ice, snow, earthy substances, smoke, steam; and even a vacuum.

[Fig. 58.

When any electrified conductor is wholly surrounded by nonconductors, so that the electric fluid cannot pass from the conductor along conductors to the earth, it is said to be insulated: thus the human body is a conductor of electricity—but if a person standing on a glass stool (as represented in the drawing) be charged with electricity, the electric fluid cannot pass from him to the earth, and he is said to be *positively electrified*, because he has more than his natural share; he is also *insulated*, and if he be touched by another person standing on the ground, sparks will be exhibited at the point of contact, where also the person touching will feel a pricking sensation.

ATTRACTION AND REPULSION EXHIBITED.

In order to illustrate certain remarkable facts in this science of an amusing character, attention must be directed to the figure A B, which is a metal stand; C is a small piece of cork or pith, which is suspended from the hook by a dry silken thread. Having rubbed an electron, as a dry rod of glass, and presented it to C, the ball will be instantaneously attracted to the glass and will adhere to it. After remaining in contact for a few seconds, if the glass be withdrawn

without being touched by the fingers, and again presented to the ball, the latter will be *repelled* instead of attracted, as in the first instance. By being touched with the finger, the ball can be deprived of its electricity, and if after this has been done we present a piece of sealing-wax in place of the glass formerly employed, the very same phenomena will take place. On the first application the ball will be *attracted*, and on the second *repelled*.

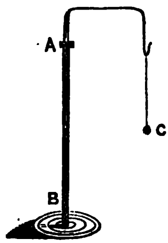

Fig. 59.

Before the young reader can perform any very important experiments with electricity, he must become possessed of an ELECTRICAL MACHINE, which is an instrument contrived for the purpose of rubbing together the surfaces of electrics and non-electrics. They generally consist of a cylinder, or plate of glass, and a piece of silk for it to rub against, covered with an amalgam, the method of preparing which we shall hereafter describe.

HOW TO MAKE AN ELECTRICAL MACHINE.

It is very easy to make a glass machine of the cylindrical form, if the maker cannot afford to buy one. First procure a common wine

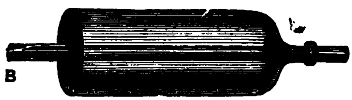

Fig. 60.

bottle of good dimensions, and thickish glass. Drill a hole through its bottom, by igniting a piece of worsted tied round it dipped in turpentine, which will do this. Through this hole and the mouth pass a spindle as represented in the cut. The end of B should be squared to fix a handle on, and the spindle should be fixed firmly in the bottle. The bottle is then to be fixed in a frame in the following manner: the end of the spindle C passes through a hole at B; and the other end at C has the handle for turning the machine.

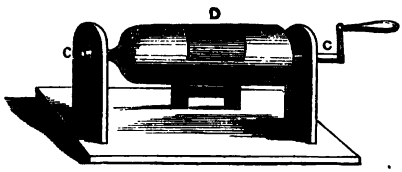

Fig. 61.

Next make a cushion of wash-leather stuffed with wool, and fastened to the top of a frame of the following figure. This frame is to

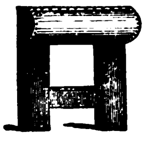
Fig. 62. Cushion.

be of such a height that the cushion shall press against the sides of the bottle, and a piece of black silk is sewn on to the top of the cushion, and hangs over the bottle D. The cushion should be smeared with an amalgam, formed by melting together in the bowl of a tobacco-pipe, one part of tin with two of zinc; to which, while fluid, should be added six parts of mercury. These should be stirred about till quite cold, and then reduced to a fine powder in a mortar, and mixed with a sufficient quantity of lard to form a thickish paste. When all is done, the machine is complete.

THE CONDUCTOR.

The electricity being generated by the friction produced between the rubber and the bottle from the motion imparted by the handle, it is necessary to draw it off for use. This is performed by what is called a conductor. This is made in the following manner. At right angles to one end of a cylinder of wood about two inches and a half in diameter, and six inches long, fix a small wooden cylinder about three-quarters of an inch in diameter, and three inches long, rounded at both ends. The other end of the larger cylinder is also to be rounded. Cover the whole with tinfoil, and mount it on a stand on a glass rod. When used, it is to be placed with the even piece in a line even with, and about half an inch from, the bottle, and it should be of such a height as to come just below the silk apron. When it is wished to charge a Leyden jar, it is to be placed at the round end of the conductor. By these simple means a great variety of pleasing experiments may be performed; but to show the various phenomena connected with this interesting study, we shall now describe an electrical machine of the newest construction, and perform our experiments with it.

THE PLATE ELECTRICAL MACHINE.

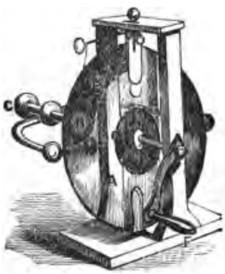

Fig. 63.

Formerly the electrical machine was made in the form of a cylinder, but now it consists of a plate A, as seen in the engraving. The plate is turned by the handle F through the rubber B B, which diffuses the excitement over the glass. The points or balls at each side of the plate carry off a constant stream of positive electricity to the prime conductor C. Negative electricity is generated by insulating the conductor to which the cushion is attached, and continuing the prime conductor with the ground, so as to carry off the fluid collected from the plate.

HOW TO DRAW SPARKS FROM THE TIP OF THE NOSE.

If the person who works the machine be supported on a stool having glass legs, and connected with the conductor by means of a glass rod, the electricity will pass from the conductor to him, and as it cannot get away, owing to the glass on which he stands being a non-conductor, any person on touching him can draw the electricity from him, which will exhibit itself in small sparks as it passes to the person who touches him. If touched on the nose, sparks of fire will issue from it.

HOW TO GET A JAR FULL OF ELECTRICITY.

A most useful piece of electrical apparatus is called the Leyden jar, here represented. It is employed for the purpose of obtaining a quantity of electricity, which may be applied to any substance. It consists of a glass jar, coated both inside and without, four-fifths of the way up, with tinfoil. A knob rises through a wooden top communicating with the inside of the jar. When it is wished to charge the jar, this knob is applied to the prime conductor of the electrical machine when in action, and a quantity of electricity being given off, the jar will remain charged with it till a connexion is made by some good conductor of electricity between the knob and the outside tinfoil. A piece of brass chain must hang from the stem that carries the knob, and connect it with the interior of the jar.

Fig. 64.

THE ELECTRICAL BATTERY.

If several of these jars be united, an enormous quantity of electricity can be collected; but in arranging them, all the interior coatings must be made to communicate by metallic rods, and a similar union must be effected among the exterior coatings. When thus arranged, the whole series may be charged as if they formed but one jar.

For the purpose of making a direct communication between the inner or outer coatings of a jar or battery, by which a discharge is

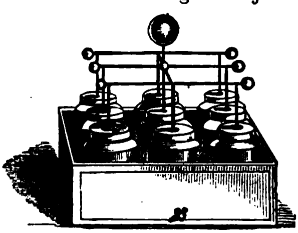

Fig. 65.

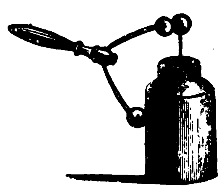

Fig. 66.

effected, an instrument called a discharging rod is employed. It consists of two bent metallic rods, terminating at one end by brass balls, and connected at another by a joint which is fixed to the end of a glass handle, and which acting like a pair of compasses, allows of the balls being separated at certain distances. When opened to the proper degree, one of the balls is made to touch the exterior coating, and the other ball is then brought into contact with the knob of the jar, when a discharge is effected; while the glass handle secures the person holding it from the effects of the shock.

DANCING BALLS AND DOLLS.

Get two round pieces of wood, A B, and coat them with tinfoil; or two pieces of metal plate; attach one of them to the prime con-

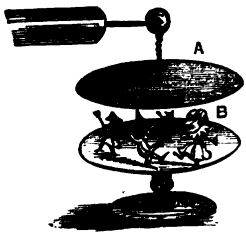

Fig. 67.


Fig. 68.

ductor by a chain, and let it hang about two or three inches from the knob. Place some pith-balls upon the bottom piece of wood B, and bring it under the other. Immediately this is done, and the upper piece is charged by electricity from the machine, the pith-balls will jump up and down, and from one to the other, with great rapidity. If some of the pith be formed into little figures, they will also dance and leap about in the most grotesque manner. The same may be made to dance by merely holding the inside of a dry glass tumbler to the prime conductor for a few minutes, while the machine is in action, and then whelm it over them, when they will jump about, to the no small astonishment of the spectators, as the cause of their motions is not quite so apparent.

THE ELECTRICAL KISS.

This amusing experiment is performed by means of the electrical stool. Let any lady challenge a gentleman not acquainted with the experiment to favour her with a salute. The lady thereupon mounts the glass stool, and takes hold of a chain connected with the prime conductor. The machine being then put in motion, the gentleman approaches the lady, and immediately he attempts to imprint the seal of soft affection upon her coral lips, a spark will fly in his face, which generally deters him from his rash and wicked intention.

RINGING BELLS.

Bells may be made to ring by electricity in the following manner. Let three small bells be suspended from a brass wire, D D, and supported by a glass pillar A, passing through bell B to the bell E. The electrical apparatus being attached to the knob E, the electricity passes down the wires D D to the bells, which are then positively electrified and attract the clappers C C, that are negatively so, in consequence of being insulated by the silken strings which are not conductors. The bells therefore attract the clappers till they are charged, when they strike against the centre bell to discharge themselves, and thus a peal is rung on the bells until the electricity is driven off.

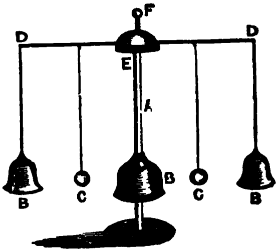

Fig. 69.

WORKING POWER OF ELECTRICITY.

This may be shown in a variety of ways. The subjoined machine will exhibit the principle upon which many ingenious toys may be made by the young philosopher. In the figure A is a wooden board or stand, B B B B, four pillars having fine wires, C C, stretched above. On these rest the rotatory wire or wheel F, having its points turned the reverse ways. By means of a chain attached to the conductor, and to the instrument at B, the electricity passes over the pillar B, up the wire C, into the wheel, and off at the points, which causes it to be turned round on an inclined plane till it reaches the top.

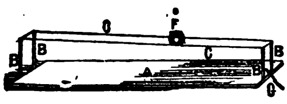

Fig. 70.

THE ELECTRIFIED WIG.

While a person is on the electrical stool, if he be charged with much electricity,

> "Each hair will stand on end,
> Like quills upon the fretful porcupine."

A wooden head, not your own, but a real wooden head, with a wig of streaming hair, and a handsome face to correspond, may be made in the following form, with a wire in the neck to support it by, and fixed in the conductor of an electrical machine. When this is put in motion, the hair will rise up as in the figure, to astonish even "Whigs," who are seldom astonished by, or deterred from anything.

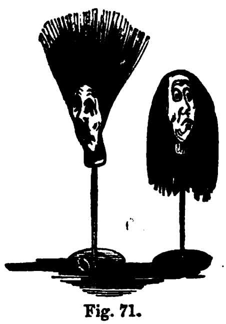
Fig. 71.

IMITATION THUNDERCLOUDS,

To show the manner in which thunderclouds perform their operations in the air. A A is a wooden stand, on which are erected two

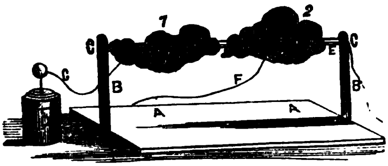

Fig. 72.

uprights, B B; C C are two small pulleys, over which a silken cord can pull easily; E is another silken line stretched across from one upright to another; on these silken cords two pieces of thin card-board covered with tinfoil, and cut so as to represent clouds, are to be fixed horizontally, and made to communicate by means of thin wires, *f* and *g*, one with the *inside*, and the other with the outside of a charged jar, D. Now, by pulling the loop of the silk line, D, the cloud 1 will be brought near the cloud 2; continue this slowly, until the clouds (which are furnished with two small brass balls) are within an inch of each other, when a beautiful flash strongly resembling lightning in miniature, will pass from one cloud to the other, restoring electrical equilibrium.

THE LIGHTNING-STROKE IMITATED.

If the jar D be put behind the stand, and the cloud 2 removed, a vessel communicating by means of a wire with the outside of the jar

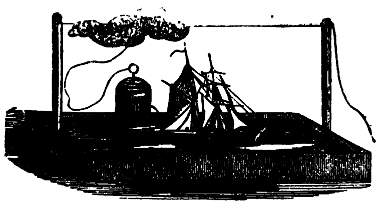

Fig. 73.

may be swum in water under the remaining cloud; the mast being made of separate pieces, and but slightly joined together. When the cloud is passed over the vessel, the mast will be struck and shattered to pieces.

THE SPORTSMAN.

This apparatus is capable of affording much amusement: A is a stand of wood, B is a common Leyden jar, out of which proceed the

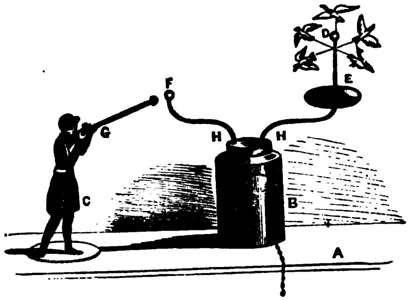

Fig. 74.

wires H H, one terminating in ball F, the other in the ball D, to which are attached a number of pith birds by silken strings; E is a shelf for the birds to rest upon; C is the sportsman; G his gun.

To put this operation in motion, the Leyden jar is to be charged with electricity by affixing a chain to the bottom part of it, and connecting it with an electrical machine in the usual manner, or by applying it to a prime conductor, when the birds will fly off the knob to which they are fixed in consequence of their being repelled. If the sportsman and gun be then turned, so that the end of his gun shall touch the knob F, an electric spark will pass from one to the other, a report will be heard, and the birds will fall down as if shot, in consequence of the electricity having been taken from the Leyden jar. There should be a communication between the sportsman and the jar formed of tinfoil, or some metal, as shown by the dotted line on the stand.

MISCELLANEOUS EXPERIMENTS WITH FRICTIONAL ELECTRICITY.

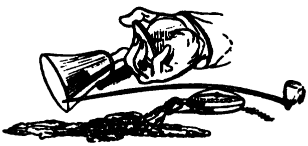

Fig. 75.

1. Lay a watch down upon a table, and on its face balance a tobacco-pipe very carefully. Next take a wine-glass, rub it quickly with a silk-handkerchief, and hold it for half-a-minute before the fire, then apply it near to the end of the pipe, and the latter, attracted by the electricity evolved by the friction and warmth in the former, will immediately follow it; and by carrying the glass around, always in front of

the pipe, this will continue its rotatory motion, the watch-glass being the centre or pivot on which it acts.

2. Warm a glass tube, rub it with a warm flannel, and then bring a downy feather near it. On the first moment of contact the feather will adhere to the glass, but soon after will fly rapidly from it, and you may drive it about the room by holding the glass between it and the surrounding objects; should it, however, come in contact with anything not under the influence of electricity, it will instantly fly back to the glass.

3. A stick of sealing-wax rubbed against a warm piece of flannel or cloth, acquires the property of attracting light substances, such as small pieces of paper, lint, &c., if instantly applied at the distance of about an inch.

4. Suspend two small pith balls, by fine silken threads of about six inches in length, in such a manner, that when at rest they may hang in contact with each other; on applying a piece of sealing-wax, excited as in the former experiment, they will repel each other.

5. Take a piece of common brown paper about the size of an octavo book, hold it before the fire till quite dry and hot, then draw it briskly under the arm several times, so as to rub it on both sides at once by the coat. The paper will be found so powerfully electrical, that if placed against a wainscotted or papered wall of a room, it will remain there for some minutes without falling.

6. And if, while the paper adheres to the wall, a light fleecy feather is placed against it, it will be attracted to the paper in the same way as the paper is attracted to the wall.

7. If the paper be again warmed, and drawn under the arm as before, and hung up by a thread attached to one corner of it, it will hold up several feathers on each side; should these fall off from different sides at the same time, they will cling together very strongly, and if after a minute they are all shaken off, they will fly to one another in a very singular manner.

8. Warm and excite the paper as before, lay it on a table, and place upon it a ball made of elder pith about the size of a pea; the ball will immediately run across the paper, and if a needle be pointed towards it, it will again run to another part, and so on for a considerable time.

9. Support a pane of glass, previously warmed, upon two books, one at each end, and place some bran underneath; then rub the upper side of the glass with a black silk handkerchief, or a piece of flannel, and the bran will dance up and down under it with much rapidity.

10. Arrange two tumblers (which must be perfectly dry and warm), on a table, in an inverted position; bridge them over with a common pane of window-glass, also clean and dry. If the centre of the pane of glass be rubbed with a stick covered with a silk handkerchief, and some pieces of cut paper are placed on a tin box just under the glass, they will exhibit electrical attraction and repulsion.

ELECTRICAL MACHINES

Are nothing more than extended surfaces of glass provided with simple means of being rubbed when turned by a proper handle; and one of the cheapest and most entertaining instruments for obtaining frictional electricity is the electrophorus, and particularly the instrument as manufactured and described by Mr. Lewis M. Stewart, of the City of London School.

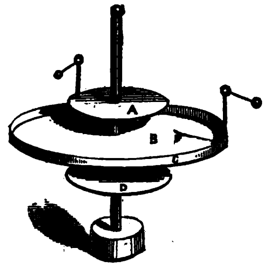

Fig. 76. Stewart's electrophorus.
A. Brass plate provided with a glass handle, and wire with pith ball attached by a thread.
B. The resinous plate.
C. The brass or tin dish containing the resinous plate, also provided with a pith ball.
D. The lower plate, supported on a glass leg, with wooden foot, and forming a convenient insulating stand.

EXCITATION OF THE ELECTROPHORUS.

Beat B, the resinous plate, smartly with a very dry piece of flannel, and hold it closely before a pith ball placed on D; the pith ball will be attracted, or any other light substance.

ILLUSTRATION OF CONDUCTORS.

After exciting the resinous plate B, place B C upon a table, and A upon B C, and connect the plate A with the table D by means of a fine wire; upon touching A with the finger and then removing it from B, both A and D will be electrified, provided the fine wire has not touched the table or any other conducting body.

ILLUSTRATION OF NON-CONDUCTORS.

Connect the wire with the glass handle of A, and proceed as before; the plate D will not be electrified, as the glass, representing a part of the connecting chain, is a non-conductor of electricity.

EFFECT OF POINTS.

Electrify A, and the little pith is repelled; if a point, such as a needle, is now brought to A, the pith gradually falls.

EFFECT OF BALLS.

Electrify A and present a round brass ball to it; the repelled pith ball does not drop, provided the spark does not pass.

With this electrophorus arrangement nearly every fact in frictional electricity shown by more expensive and elaborate apparatus may be displayed; and it is certainly one of the best instruments for class instruction, as the resinous plate, when once thoroughly excited, will remain in action for many hours.

Fig. 77.

EXPERIMENTS WITH VOLTAIC ELECTRICITY, OR GALVANISM.

1. PLACE a thin plate of zinc upon the upper surface of the tongue, and a half crown or a piece of silver on the under surface. Allow the metals to remain for a little time in contact with the tongue before they are made to touch each other, that the taste of the metals themselves may not be confounded with the sensation produced by their contact. When the edges of the metals which project beyond the tongue are then suffered to touch, a galvanic sensation is produced, which it is difficult accurately to describe.

2. Place a silver teaspoon as high as possible between the gums and the upper lip, and a piece of zinc between the gums and the under lip. On bringing the extremities of the metals into contact, a very vivid sensation, and an effect like a flash of light across the eyes, will be perceived. It is singular, that this light is equally vivid in the dark and in the strongest light, and whether the eyes be shut or open.

3. Take a piece of copper of about six inches in width, and put upon it a piece of zinc of rather smaller dimensions, inserting

a piece of cloth, damped with dilute sulphuric acid, of the same size as the zinc, between them ; place a leech upon the piece of zinc, and, though there appears nothing to hinder it from crawling away, yet it will hardly pass from the zinc to the copper, because, as soon as its damp body touches the copper it receives a galvanic shock, and of course retires to its resting place, the zinc.

4. Plunge an iron knife into a solution of sulphate of copper, (bluestone), by chemical action only it will become covered with metallic copper. Immerse in the same solution a piece of platinum, taking care not to let it touch the iron, and no deposition of copper will take place upon it ; but if the upper ends of the metals are brought into contact with each other, a copious deposition of copper will soon settle upon the platinum likewise.

WITH METAL PLATES IN WATER.

If we take two plates of different kinds of metal, platina or copper, and zinc, for example, and immerse them in pure water, having wires attached to them above, then if the wire of each is brought into contact in another vessel of water, a galvanic circle will be formed, the water will be slowly decomposed, its oxygen will be fixed on the zinc wire, and at the same time a current of electricity will be transmitted through the liquid to the platina or copper wire, on the end of which the other element of water—namely, the hydrogen, will make its appearance in the form of minute gas bubbles. The electrical current passes back again into the zinc at the points of its contact with the platina, and thus a continued current is kept up, and hence it is called a galvanic circle. The moment the circuit is broken by separating the wires, the current ceases, but is again renewed by making them touch either in or out of the water. If a small quantity of sulphuric acid be added to the water, the phenomenon will be more apparent. The end of the wire attached to the piece of platinum or copper is called the positive pole of the battery, and that of the wire attached to the zinc the negative pole.

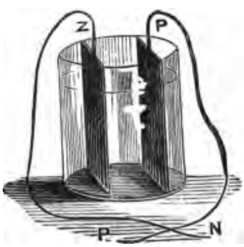

Fig. 78.

The current of electricity here generated will be extremely feeble,

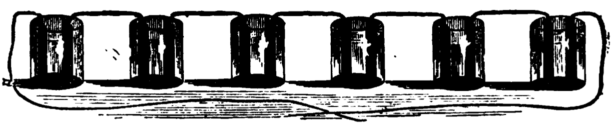

Fig. 79.

but this can be easily increased by multiplying the glasses and the number of the pieces of metal. If we take six such glasses instead of one, partially fill them with dilute sulphuric acid, and put a piece of zinc and copper into each, connecting them by means of copper wire from glass to glass through the whole series, a stronger current of electricity will be the result. The experimenter must be careful not to let the wire and zinc touch each other at the bottom of the tumblers, and must also remember that the copper of glass 1 is connected with the zinc of glass 2, and so on.

TO MAKE A MAGNET BY GALVANISM.

To effect this, make a connexion between the poles of the above or any excited battery with the two ends of a wire formed into a spiral coil, by bending common bonnet-wire closely round a cylinder, or tube, of about an inch in diameter; into this coil introduce a needle, or piece of steel wire, laying it lengthways down the circles of the coil. In a few minutes after the electric fluid has passed through the spiral wire, and consequently round the needle or wire, the latter will be found to be strongly magnetized and to possess all the properties of a magnet.

EFFECTS OF GALVANISM ON A MAGNET.

If a galvanic current, or any electric current, be made to pass along a wire, under which and in a line with it a compass is placed, it will be found that the needle will no longer point north and south, but will take a direction nearly across the current, and point almost east and west.

CHANGE OF COLOUR BY GALVANISM.

Put a tea-spoonful of sulphate of soda into a cup, and dissolve it in hot water; pour a little cabbage blue into the solution, and put a portion into two glasses, connecting them by a piece of linen or cotton cloth previously moistened in the same solution. On putting one of the wires of the galvanic pole into each glass, the acid accumulates in the one, turning the blue to a red, and the alkali in the other, rendering it green. If the wires be now reversed, the acid accumulates eventually in the glass where the alkali appeared, while the alkali passes to the glass where the acid was.

TO TAKE AN ELECTROTYPE COPY OF A WAX SEAL.

Having selected a good and perfect seal, thoroughly blacklead the surface with the ordinary plumbago, laid on and polished with an old and soft tooth-brush. Into the side of the seal, in a portion of the wax seal not covered with the impression, melt in gently a very thin copper wire, so that the surface of the upper side of the wire shall be flush with the seal, and blacklead this juncture carefully; then wind the other end of the thin copper wire round a piece of amalgamated zinc five inches long, one-eighth of an

inch thick, and three-quarters of an inch broad, as in this arrangement the seal takes the place of the copper element in the simple voltaic circle.

In half-a-pint of boiling water dissolve as much powdered sulphate of copper, or bluestone, as the water will take up; place this, when cold, in an ordinary tumbler, and having rolled a piece of brown paper three or four times round a ruler one inch thick, close the side and bottom with sealing-wax, to make a porous cell. Hold the brown paper tube or cell over the tumbler containing the solution of sulphate of copper, and pour into it a mixture of five parts water and one part oil of vitriol (these latter must be mixed beforehand, and should be quite cold): as the acid is poured into the brown paper cell, let it sink into the sulphate of copper solution, and then, finally, having bent the wire that unites the seal to the amalgamated zinc, place the latter in the brown-paper vessel, and the former into the solution of copper in the tumbler, and in about twelve hours a beautiful impression of the wax seal will be obtained in copper.

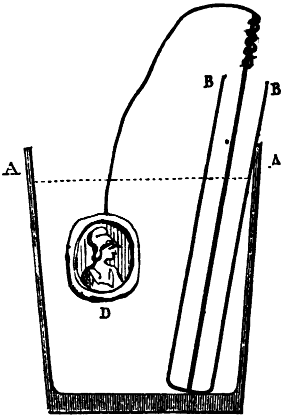

Fig. 80. Electrotyping. A A. The tumbler containing the solution of sulphate of copper.
B B. The porous cell made of brown paper, holding the dilute acid, and the amalgamated zinc plate.
D. The wax seal black-leaded, attached to zinc plate by the connecting wire.

N.B. Zinc is easily amalgamated by dipping it first into some dilute sulphuric acid, and then, having a little mercury in a plate, it may be rubbed on by means of a flat piece of stick covered with flannel.

EXPERIMENTS WITH MAGNETISM.

1. We have said that the agency of the magnet can be imparted to steel; this may be done in a very easy way. If you pass a magnet (which may be either natural or artificial), over a sewing-needle several times from the eye to the point, the needle will acquire the principle and attract iron filings in the same manner as a natural magnet would do. But the part of the magnet which you apply to the needle must be the north pole, and you must not pass it over the needle backwards and forwards, but lift it always from the point, and again begin from the eye. Suppose you wish to impart the principle to a small bar of tempered steel, tie the piece to be magnetised to a poker with a piece of silk, and hold the part of the poker to which it is attached in the left hand; take hold of the tongs

a little below the middle, with the right hand, and rub the steel bar with them, moving the tongs from the bottom to the top and keeping them steadily in a vertical position all the time. About a dozen strokes on each side will impart quite sufficient magnetical power to the bar to enable the operator to lift up small pieces of iron and steel with it. The lower end of the bar should be marked before it is fastened to the poker, so that the poles may be readily distinguished from each other when it is taken off; the upper end being the south pole, and the lower the north.

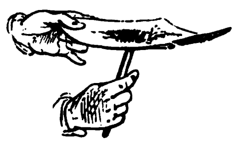
Fig. 81.

2. Scatter some iron filings upon a piece of paper, and hold a magnet underneath it. The instant the contact takes place, the filings will raise themselves upright, and fall down as soon as the magnet is withdrawn. The effect is singular, and indeed very amusing; the diminutive iron particles rising and falling as if by supernatural agency.

MAGNETIC SWAN.

Form a swan of cork, and place within its beak a little bit or steel strongly magnetised, then cover it with a thin coating of white wax, and, to render the image more complete, glass beads may be put in its head to represent the eyes. The swan being thus made, you must provide it with a lake to swim in. A basin of water may supply

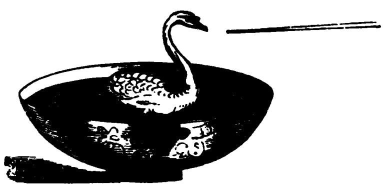
Fig. 82.

this, and when your lake is ready and the swan placed in it, the next object is to make it swim about. This you may easily accomplish by holding in your hand a magnetic bar, on which the north and south poles are marked. Show the north pole of the wand to the swan, and the little creature will immediately follow it, moving very gently over the water; you may thus lead it about, and when you wish it to retire, present the south pole of the wand to it, and, like a good, obedient bird, it will readily recede and turn back.

If you wish to make a magnetic wand, you may do so by procuring a hollow cane eight or nine inches in length, and half an inch thick, and a small steel bar well magnetised. Put this bar in the cane, and

close it at both ends by screwing on small ivory tops differing in shape, or having some marks by which you may in an instant recognise the north and south ends of the rod. With this wand you may direct the course of any floating figure you may choose to fashion.

TO SHOW THE EFFECT OF MAGNETISM BY MEANS OF A BALANCE.

Suspend a magnet in one of the scales of a very delicate balance, and carefully adjust it by putting weights into the other scale; when thus counterpoised, hold a piece of iron under the scale to which the magnet is attached, and it will immediately descend. If, instead of the magnet, a piece of iron be attached to the scale, and the magnet held under the iron, the scale will descend as before.

TO SHOW THAT THE POWER OF ATTRACTION RESIDES CHIEFLY AT THE POLES.

Fig. 83.

Place some iron filings upon a table, and then put amongst them a magnetic rod or bar. The filings will immediately adhere to the ends of the bar or rod, but not to the middle or centre, where the power of attraction is very little exerted, if at all.

TO SHOW THE REPULSION OF THE POLES.

The north poles of two magnets repel each other, and the same happens with the south poles, for the magnetic attraction is exerted only between the contrary poles. Thus, if you fix two magnetised needles in two pieces of cork, and place them in a basin of water, and they are in a parallel position with the same poles together, that is north to north or south to south, they will mutually repel each other; but if the contrary poles point to one another, then they will be attracted and draw close together.

TO SHOW THE DIRECTIVE POWER OF THE MAGNET.

If you balance a bar of steel or an untouched needle horizontally upon a pivot or centre, it will remain stationary; but magnetise the same, as already indicated, and place it again on its centre, and you will see that it turns round, and does not stop until its north pole is in the direction of the north pole of the earth.

TO MAKE ARTIFICIAL MAGNETS.

This may be done by stroking a piece of hard steel with a natura or artificial magnet. Take a common sewing-needle and pass the north pole of a magnet from the eye to the point, pressing it gently in so doing. After reaching the end of the needle, the magnet must not be passed back again towards the eye, but must be lifted up and applied again to that end, the friction being always in the same

direction. After repeating this for a few times, the needle will become magnetised, and attract iron filings, &c.

HOW TO MAGNETISE A POKER.

Hold it in the left hand in a position slightly inclined from the perpendicular, the lower end pointing to the north, and then strike it smartly several times with a large iron hammer, and it will be found to possess the powers of a magnet, although but slightly.

THE WATCH MAGNETISED.

Borrow a watch from the company, and inquire if it will go when laid on the table. Then place it just over the point at which a magnet is fixed underneath the top of the table, and the magnet will attract the balance-wheel of the watch, and cause it to stop.

TO SHOW MAGNETIC REPULSION AND ATTRACTION.

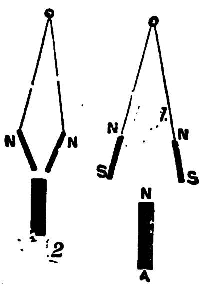

Fig. 84.

Suspend two short pieces of iron wire, N S, N S, so that they will hang in contact in a vertical position. If the north pole of a magnet N be now brought to a moderate distance between the wires, they will recede from each other as in No. 1.

The ends S S being made south poles by induction from the north pole N, will repel each other, and so will the north poles N N. This separation of the wires will increase as the magnet approaches them, but there will be a particular distance at which the attractive force of N overcomes the repulsive force of the poles S S, and causes the wires to converge as in No. 2; the north poles N N still exhibiting their mutual repulsion.

POLARITY OF THE MAGNET.

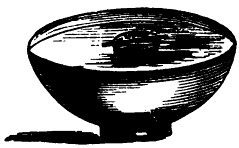
Fig. 85.

The best method of proving this is to take a magnet or a piece of steel rendered magnetic, and to place it on a piece of cork by laying it in a groove cut to receive it. If the cork be placed in the centre of a basin of water, and allowed to swim freely on its surface, so that it is not attracted by the sides of the basin, it will be found to turn its north pole to the north, and its south pole to the south, the same as the mariner's compass. If you fix two magnets in two pieces of cork, and place them also in a basin of water, and they are in a parallel position with the same poles together, that is, north to north, and south to

south, they will mutually repel each other; but if the contrary poles point to one another, as north to south, they will be attracted.

NORTH AND SOUTH POLES OF THE MAGNET.

Each magnet has its poles, north and south—the north or south poles of one magnet repel the north and south pole of another. If a magnet, as in the following figure, be dipped in some iron filings, they will be immediately attracted to one end. Supposing this to be the north pole, each of the ends of the filings, not in contact with the magnet, will become north poles, while the ends in contact will by induction become south poles. Both will have a tendency to repel each other, and the filings will stand on the magnet as in the figure.

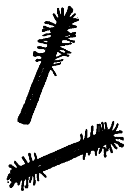

Fig. 86.

THE MAGNETIC FISH.

Fish are to be purchased at the toy-shops, by which the young "magnétique" may perform this experiment; they are made hollow, and will float on the water. In the mouth of each should be inserted a piece of magnetic wire. The angling rod is like any other rod, and has a silken thread for a line, and an iron hook also strongly magnetised. To catch the fish it is only necessary to put the hook in contact with the noses of the fish, and they will be taken without any of the baits mentioned in the "Young Angler." (Routledge and Co.)

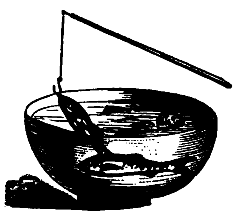

Fig. 87.

HORSE-SHOE MAGNETS.

The form of a horse-shoe is generally given to magnetised bars when both poles are wanted to act together, which frequently happens in various experiments, such as for lifting weights by the force of magnetic attraction, and for magnetising steel bars by the process of double touch, for which they are exceedingly convenient. The following is a method of making a powerful magnetic battery of the horse-shoe form. Twelve bars or plates of steel are to be taken, and having been previously bent to the required form—that is, the horse-shoe shape—they are then bound together by means of rivets at their ends; before being finally fastened, they are each separately magnetised, and afterwards finally united.

Fig. 88.

Horse-shoe magnets should have a short bar of soft iron adapted to connect the two poles, and should never be laid by without such

a piece of iron adhering to them. Bar magnets should be kept in pairs with their poles turned in contrary directions, and they should be kept from rust. Both kinds of magnets have their power not only preserved but increased by keeping them surrounded with a mass of dry filings of soft iron, each particle of which will re-act by its induced magnetism upon the point of the magnet to which it adheres, and maintain in that point its primitive magnetic state.

TO MAKE ARTIFICIAL MAGNETS WITHOUT THE AID EITHER OF NATURAL LOADSTONES OR ARTIFICIAL MAGNETS.

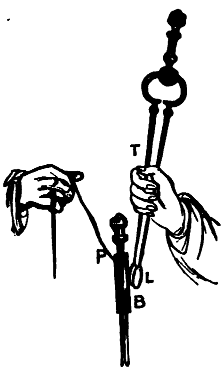

Fig. 89.

Take an iron poker and tongs, or two bars of iron, the larger and the older the better, and fixing the poker upright, hold to it with the left hand near the top P by a silk thread a bar of soft steel about three inches long, one fourth of an inch broad, and one twentieth thick; mark one end, and let this end be downwards. Then grasping the tongs T with the right hand a little below the middle, and keeping them nearly in a vertical line, let the bar B be rubbed with the lower end L of the tongs, from the marked end of the bar to its upper end, about ten times on each side of it. By this means the bar B will receive as much magnetism as will enable it to lift a small key at the marked end; and this end of the bar being suspended by its middle, or made to rest on a joint, will turn to the north, and is called its north pole, the unmarked end being the south pole. This is the method recommended by Mr. Caxton, in his process, which he regarded as superior to those in former use, and of which a more detailed account will be found in his interesting volume.

EXPERIMENT TO SHOW THAT SOFT IRON POSSESSES MAGNETIC PROPERTIES WHILE IT REMAINS IN THE VICINITY OF A MAGNET.

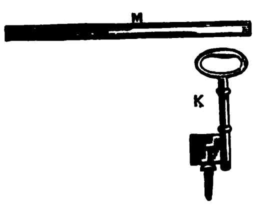

Fig. 90.

Let M be a magnet and K a key, held horizontally near one of its poles, or near its lower edge. Then, if another piece of iron, such as a small nail, be applied to the other end of the key, the nail will hang from the key, and will continue to do so while the magnet is slowly withdrawn; but when it has been removed beyond a certain distance, the nail will drop from the key, because the magnetism induced in the

key becomes at that distance too weak to support the weight of the nail. That this is the real cause of its falling off may be proved by taking a still lighter fragment of iron, such as a piece of very slender wire, and applying it to the key. The magnetism of the key will still be sufficiently strong to support the wire, though it cannot the nail, and it will continue to support it even when the magnet is yet further removed; at length, however, it drops off.

TO SUSPEND A NEEDLE IN THE AIR BY MAGNETISM.

Place a magnet on a stand to raise it a little above the table; then bring a small sewing-needle containing a thread within a little of the magnet, keeping hold of the thread to prevent the needle from attaching itself to the magnet. The needle, in endeavouring to fly to the magnet, and being prevented by the thread, will remain curiously suspended in the air like Mahomed's coffin.

ELECTRO-MAGNETISM.

The identity of magnetism with electricity alluded to in a former paragraph, has led to the formation of a new science under the above name, and to some of the interesting experiments connected with it we shall briefly allude, for the amusement of the young reader.

POWER OF THE ELECTRO-MAGNET.

The same influence which affects the magnetic needle already described, will also communicate magnetism to soft iron. If a bar of that metal bent, as in the drawing, be surrounded with a common bonnet-wire, or a copper wire prevented from touching the iron by a winding of cotton or thread, and then if a current of voltaic electricity be sent through the wire, the bar becomes a powerful magnet, and will continue so as long as the connexion with the battery is preserved. On breaking the contact the magnetism disappears. This experiment may be easily made by the young reader with a horse-shoe magnet surrounded by several coils of wire; P is the positive, and N the negative pole.

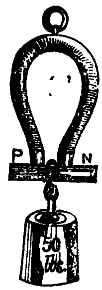

Fig. 91.

DIP OF THE NEEDLE.

Another remarkable and evident manifestation of the influence of the magnetism of the earth upon the needle is the inclination or dip of the latter, which is a deviation from its horizontal place in a downward direction in northern regions of its north, and in southern regions of its south pole. The causes of the dipping of the needle are yet unexplained. In balancing the needle on the card, on account of this dipping, a small weight or moveable piece of brass is placed on one end of the needle, by the shifting of which either nearer to or further from the centre, the needle will always be balanced.

VARIATION OF THE NEEDLE.

The magnetic needle does not point exactly north and south, but the north pole of the needle takes a direction considerably to the west of the true north. It is constantly changing, and varies at different parts of the earth, and at different times of the day.

THE MARINER'S COMPASS AND EXPERIMENTS WITH A POCKET COMPASS.

The mariner's compass is an artificial magnet fitted in a proper box, and consists of three parts—1, the box; 2, the card or fly; and

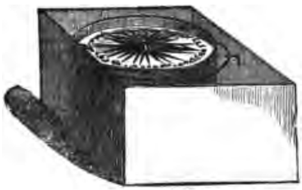

Fig. 92.

Fig. 93.

3, the needle. The box is suspended in a square wooden case, by means of two concentric brass circles called gimbals, so fixed by brazen axes to the two boxes, that the inner one, or compass-box, retains a horizontal position in all motions of the ship. The card is a circular piece of paper which is fastened upon the needle, and moves with it. The outer edge of the card is divided into thirty-two points, as shown in the engraving, called points of the compass. The needle is a slender bar of hardened steel, having a hollow agate cup in the centre, which moves upon the point of a pivot made of brass.

USEFUL AMUSEMENT WITH THE POCKET COMPASS.

Pocket compasses are to be bought for five or six shillings, and may be used in many ways. In travelling over mountains or a wide extended moor, they are indispensably necessary; and no one should go a tour into Wales, Scotland, or the lakes without such a companion, and it will be a very useful and amusing exercise for any young person to take the bearings of his own or some particular locality, and make out what may be called a bearing card. This he may easily do in the following manner. Supposing he wishes, for instance, to take the bearings of his own house, he has nothing to do but set his pocket compass upon a map of the district—a county map will do very well, unless his house stands on the verge of a county, then two county maps will be necessary. He must make the north of the map exactly coincide with the north, as indicated by his compass, and having fixed his map in this situation, he

should take a ruler and piece of paper, and dot down the exact bearings of each important town, or place, or village, around him. Let him suppose himself, for instance, in the town of Cambridge, and laying down his map as indicated by the compass, north to north and south to south, he will find the following places due north —Wilberton, Wentworth; Little Wilbraham, Teversham, due east; Duxford and Chesterfield, south; Coton and St. Neots in Huntingdonshire, west. The other points of the compass may be filled up in the same manner. Should, therefore, our young friend be upon any elevated situation near his own dwelling, or upon any other elevated spot from which the bearings have been taken, he will be able to inform his young friends that such and such a place lies in such a direction, that this place lies due north, the other north-west, a third south-east, the fourth south-west, &c. &c.; and the information so obtained will be serviceable to himself in many important matters.

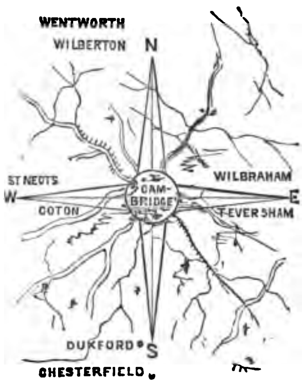

Fig. 94.

INTERESTING PARTICULARS CONCERNING THE MAGNET.

Fire-irons which have rested in one position in a room during the summer months are often highly magnetic.

Iron bars standing erect, such as the gratings of a prison cell, or the iron railings before houses, are often magnetic.

The uppermost of the iron tire round a carriage-wheel attracts the north end of a magnet, and has hence south polarity, while the lower end attracting the south end of the same, has north polarity.

Magnetism may be made to pass through a deal board; to exhibit which, lay a needle on the smooth part above, and run a magnet along the under side, and the needle will be found to follow the course of the magnet. A magnet dipped into boiling water loses part of its magnetism, which, however, returns upon its cooling.

A sudden blow given to a magnet often destroys its magnetic power.

CONCLUSION.

The preceding experiments in electricity, galvanism, and magnetism, we have selected for the simple illustrations which they offer of some of the principles of those branches of philosophy; more elaborate experiments we have refrained from inserting, as although, perhaps, more astonishing and impressive in their effects, the costly apparatus which they require raise them far above the means of most boys, for whose instruction and amusement we cater.

AEROSTATION.

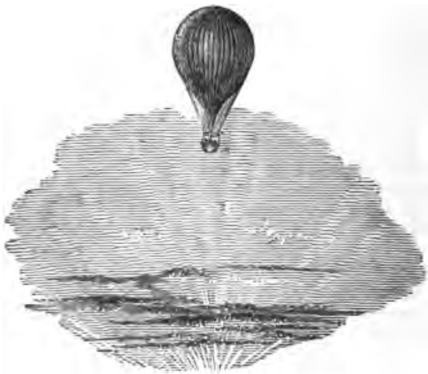

Fig. 95. Balloon.

FROM the remotest ages of which we have any record, the regions of the air have been a subject of intense curiosity to man. For many centuries fanaticism considered them as the abode of evil spirits and demons; but when knowledge poured her rich stores upon man, he began to consider that air, like water, was a fluid, which he might render subservient to his purposes, and conceived the idea of flying. The first trials of this mode of progression seem to have been achieved by Grecian skill, and the most celebrated imitation of flying on record, of ancient times, is that of the renowned geometrician of Tarento, Archytas, who constructed a pigeon of wood which could fly, but which, however, if it fell to the ground, could not raise itself again. In Rome, in the time of Nero, it is said that a man raised himself up by means of wings, but that he lost his life in the attempt. In Scotland, in the reign of James IV. an Italian adventurer made an essay at flying, and the latest endeavour of the kind recorded in history, and which to a certain extent was successful, was that of the Marquis de Bacqueville, who, in 1742, rose, by the aid of wings alone, from his residence on the Quai des Theatins, Paris, and directed his flight across the Seine,

towards the gardens of the Tuileries; but just as he had advanced half way, he appeared to lose all command of his movements, and his wings ceasing to act, he fell against one of the floating machines belonging to the Parisian washerwomen, which line the arches of the Pont Royal, and had his leg broken in addition to other serious injuries.

Flying being found, even in early times, useless, other means of moving in the air were next sought after, and the possibility of rising from the earth, on the same principle that the clouds rise and keep afloat, became the new subject of speculation. In the fourteenth century, an Augustine friar, Father Albert, of Saxony, suggested the first correct notion of rising in the air by means of a balloon. The quiet of the cloisters had furnished this monk, as it had many other inhabitants of those silent mansions of religion, with sufficient leisure to explore the mysteries of science. He had written a commentary upon the physical works of Aristotle, and was probably acquainted with the doctrines of Archimedes, who had established the principle, that a body must remain suspended in a fluid denser than itself. However this might be, Father Albert conceived that, "since fire is more attenuated than air, and floats above the region of our atmosphere, a portion of such substance enclosed in a light hollow globe, would rise to a certain height." This theory was taken up and agitated by various speculators, but mostly in the cloisters, until Stephen and Joseph Montgolfier, brothers, paper makers of Ammonay, near Lyons, in France, put it into practice about the latter end of the last century. Though not favoured by a liberal education, the Montgolfiers were impelled by natural ingenuity to acquire more knowledge than is generally met with in the class of manufacturers to which they belonged. Stephen was attached to chemistry, Joseph to mathematics; but both of them had directed their attention to the ascent and floating of clouds in the atmosphere. The result of their speculations was the supposition that a factitious cloud, formed of very thin vapour and enclosed in a light bag of great dimensions, would ascend into the higher regions. Their first experiment was made in November, 1782, with a bag of fine silk filled with rarefied air, which answering perfectly, they tried the experiment on a larger scale; and on the 19th of October, 1783, exhibited before the king and court of France, at Versailles, a balloon, having a basket attached to it, in which were a sheep, a cock, and a duck; in about eight minutes the fire which supplied the balloon with rarefied air went out, and the apparatus descended without injuring the aeronauts. This last trial being so completely successful, Monsieur Pilâtre de Rosier offered to ascend in a similar machine; and on the 21st of November, 1783, accompanied by the Marquis d'Arlandes, he made the first aeronautical voyage ever attempted by man.

The balloon used by Monsieur Rosier was highly ornamented, being composed of silk, decorated with gold and spangles, and scarlet velvet; the car was a gallery large enough for the voyager to walk round, and the centre of it was hollow, containing an iron grate or

brazier. The principle of the machine was that of a fire-balloon, its ascensive power being produced by the rarefaction of atmospheric air, by means of a large fire being kept burning in the grate, under the lower part of the balloon, which was open for the purpose of receiving the heated air; and that the fire and supply of rarefied air might be regulated at pleasure, port-holes were made in the gallery towards the grate. So long as the aeronaut wished to remain in the air, he was obliged to furnish this fire with fuel; and when he purposed descending, he suffered it to decline. This species of balloon is known by the title of the Montgolfière, from the original inventors, the Montgolfiers, and is an exceedingly dangerous one, on account of its liability to take fire from the burning materials in the grate, and indeed the greatest number of accidents which have befallen aeronauts have been through its perilous construction; Monsieur Rosier himself perished, on the 15th of June, 1785, through the conflagration of the machine in which he and a fellow voyager, Monsieur Romain, were travelling, with the intention of crossing from Boulogne-sur-Mer to England. The apparatus was consumed in the air, and both the luckless gentlemen were dashed to pieces upon the rocks by the seashore from Calais to Boulogne.

At the same time that the Montgolfiers were experimenting upon balloons filled with rarefied air, Monsieur Charles, professor of philosophy in Paris, was endeavouring to inflate one with hydrogen gas; and, after enduring much ridicule for attempting to invent another mode of doing that which was already done, achieved his design, and on the 1st of December, 1783, accompanied by Monsieur Robert, he ascended from the Champ de Mars, and landed in safety, after a completely successful voyage.

To these original discoveries of the science of aerostation many adventurers succeeded in different parts of Europe, and the superiority of the hydrogen gas over the Montgolfière, or heated air balloon, was fully established; for five persons perished in the space of a few years, through the accidental combustion of their machines, but too appropriately termed *fire* balloons.

At the present time balloons are filled with carburetted hydrogen gas, the common coal gas, which is considerably cheaper than the hydrogen, and can be procured far more readily, inasmuch as the filling of a balloon, which in former periods cost the labour of two or three days at an enormous expense, can now be done in as many hours. For the discovery of the applicability of this gas to aeronautical purposes, we are indebted to Mr. Charles Green, the intrepid voyager of our own days, and who has also invented what he terms a guide rope, that is, a rope of a thousand feet in length and upwards, which, when the balloon has quitted terra firma, and circumstances render its use advisable, is lowered from the car by means of a windlass. When the specific gravity of the machine is increased, and he begins to descend, the tail of the guide rope, trailing on the ground, acts like the discharge of a quantity of ballast, and checks her further descent, and she continues progressing on the level so produced, until she attains a reascensive power, and quits the earth with all

her resources of ballast and gas the same as she had before her course was arrested by the increased weight. This contrivance, simple as it is, is of invaluable benefit to the aeronaut, who by augmenting or diminishing the quantity of rope he lets out, proportionately increases or lessens the space between himself and the earth, and so does away with the necessity of employing ballast to such an extent as heretofore; indeed, according to the old system of discharging ballast, whenever the balloon became so heavy with moisture as to descend, and to release some portion of the gas, when, from the diminution of the ballast, she rose too high, it was impossible for an aeronaut to prolong his voyage beyond thirty-six hours; now, however, he may continue it for almost as many days, should it be requisite.

The honour of making the first aerial expedition in England has usually been ascribed to a foreigner, Signor Vincenzo Lunardi, but in reality a Mr. James Tytler claims the merit, he having ascended in a Montgolfière from Comely-gardens, Edinburgh, on the 27th of August, 1784, nineteen days before the signor, who ascended from the Artillery-grounds, Moorfields, on the 15th of the following September. Lunardi repeated his ascents in various parts of England and Scotland, and afterwards returned to Italy. Monsieur Blanchard visited England after Lunardi, and made many ascents, and in company with Dr. Jefferies, on a clear frosty day, the 7th of January, 1785, crossed the British Channel from Dover, and landed in safety, after a dangerous voyage of two hours and a half, on the confines of a forest near Calais. This aeronaut made thirty-six voyages through the air, and gained a large sum of money by them. Monsieur Garnerin, another distinguished French aeronaut, who visited England, is celebrated for having been the first person who successfully descended from a balloon in a parachute. This machine consisted of thirty-two gores of white canvas, formed like an umbrella, of twenty-three feet in diameter, at the top of which was a round piece of wood of ten inches in breadth, having a hole in its centre to admit short pieces of tape to fasten it to the gores of the canvas; about four and a half feet below the top was a hoop of eight feet in diameter, affixed by a string from each seam, and below the hoop the car, made of basket-work covered with canvas, was suspended. The parachute is by no means that modern invention which is generally supposed, for Father Loubère, in his account of Siam, published nearly two hundred years since, describes a machine of the same kind as being in use there, as a means of descending from great heights; in Europe it certainly was not employed for that purpose till the year 1783, when M. le Normand proved its efficacy by letting himself down from the windows of a lofty house in the city of Lyons. The aeronaut Blanchard was the first who applied it to the balloon, and after trying several experiments by letting down dogs and various animals from different heights, during some of his excursions, he attempted the descent himself at Basle, in 1793; but through some mismanagement the parachute did not expand fully, and the traveller coming to the ground too rapidly, had the misfortune to have his leg broken. Garnerin's first successful descent was on the 21st of

October, 1797, at Paris, and on the 21st of September, 1802, he made his third trial with a parachute, the first time such a machine was ever used in England. Various aeronauts have since endeavoured to diminish the inherent perils of parachute descents by different inventions, but without success.

On the 24th of July, 1837, Mr. Cocking made an ascent from Vauxhall-gardens in a parachute appended to Mr. Green's balloon: this parachute was of a shape exactly the reverse of Mr. Garnerin's, that is, it was like an umbrella turned upside down, and so constructed as always to remain expanded. This shape was adopted in order to correct two great defects in the old fashion, viz., its oscillatory motion when descending, and the time which frequently elapsed ere the machine fully expanded to its umbrella-like form; but so far from remedying these faults, its principles were perfectly erroneous, and when the unfortunate aeronaut detached himself from the balloon, the strings of his parachute gave way, and he was precipitated to the earth and killed upon the spot.

The aerial voyager has sometimes opportunities of observing the grandest effects in the clouds which it is possible for the human mind to contemplate. The rising and setting of the greater and lesser lights of the universe in regions too remote for him to penetrate, the forked lightning flashing its unearthly blaze, and the tempestuous clouds beneath his feet, rolling in mighty masses as far as the eye can reach, are seen by him in all their magnificence; whilst the thousand beauties of the panoramic view stretched below him in all the brilliancy of a noontide sun, or the quiet twilight stealing gently over the face of the earth, receive additional charms from the elevation from which they are viewed. In 1785 Monsieur Charles beheld a most magical spectacle during a voyage he made; for, just as the sun had set, the machine in which he was, shot upwards with such celerity as to rise nearly two miles in ten minutes. At this height he saw the sun again in its full glory, and from his lofty station in the heavens he once more contemplated the parting beams of the fading luminary, until it sunk below the horizon. The evening mists, gradually rising from the ground, collected into clouds and, hanging in dense masses, screened the earth from his sight; and when the moon rose in silent majesty, and poured forth her mild beams, her rays tinged with various hues the everchanging forms of the accumulated vapours which floated beneath him. A voyage performed by Monsieur Tester, in 1786, is remarkable for the various events which attended it, and is deserving of a slight notice. After having risen to the height of two thousand eight hundred feet, he descended at half-past five in the afternoon, and alighted in a cornfield in Montmorency, where, being employed in gathering stones for ballast, without leaving his car, he was surrounded by a great number of peasants. The proprietor of the field, seeing his corn thus trampled upon, insisted on being paid for the damage his visitor had occasioned, and holding fast the balloon by the stay, proceeded, assisted by the peasants, to parade his prisoner through the village. Tester seized the first opportunity to cut the cord, and taking an

unexpected leave of the astonished peasants, rose again to the region of the clouds. At about seven o'clock he heard the blast of a horn, and descried huntsmen below in full chase, to contemplate which scene he opened the valve, and descended between Etuan and Varville. He was again collecting some ballast, when the huntsmen galloped up to him; and for the third time he rose into the air, passing through a dense body of clouds, where thunder and lightning followed each other without intermission. The balloon reached the altitude of three thousand feet, and in this region the intrepid aeronaut sailed until half-past nine o'clock, when he observed the final setting of the sun, and remained enveloped in darkness, amidst a mass of thunder-clouds. The lightning flashed on all sides, the loud peals of thunder were incessant, and snow and sleet fell copiously around him for the space of three hours; after which period, to his inexpressible pleasure, the stars showed their pale fires. At a quarter before four o'clock he made his final descent, having seen the first grey dawn of morning and rising of the sun.

The most memorable voyage ever attempted, was that performed by Messrs. Holland, Monck Mason, and Charles Green, on the 7th of November, 1836. The balloon, called the Royal Vauxhall Balloon, was of stupendous size, being sixty feet in height and fifty in breadth; and every arrangement was made by the travellers for a long voyage, in the shape of cloaks, carpet-bags, lamps, barometers, wine-jars, spirit-flasks, coffee, and other necessaries. At half-past one in the afternoon the cords were cut, and the mighty vessel rose proudly into the air, and at five minutes past four she neared the city of Canterbury, when the travellers indited a short letter to the mayor of that city, and dispatched it by a small parachute, a novel kind of post conveyance. At forty-eight minutes after four, the waves breaking on the beach gave evidence that they were near the British Channel; and as they proceeded on their quiet way, the twilight, deepening into murky gloom, hid the English coast from their view, save that, through some scattered lights and the brilliant glare of the lighthouse, they were certain that Dover was yet within their ken. The evening shades had fully set in ere they gained a glimpse of the Calais lights; and there being no moon to define objects by the soft touches of her silvery rays, the effect was one of great grandeur; and when, still later in the night, when it was perfectly dark, they passed over the city of Liége, the streets and houses marked out by the lights in them, and the numerous fires blazing in the iron works in the neighbourhood, formed a picture of consummate beauty. As the hours rolled on, and midnight passed silently by, the heavens assumed a depth of colour rivalling a positive black in intensity of tint, from out of which the stars glittered with additional lustre; earthwards no object was to be seen, the weary artisans having long before betaken themselves to their repose. Towards five o'clock in the morning the dawn gradually broke, and disclosed to the travellers the mighty river Rhine, which seemed to lose itself in the vapours which enshrouded the valleys and rested upon the hills; and as the brightness of the light increased, the stars

by degrees disappeared, the morning star being the last to make its exit. At a quarter-past six, when at the height of nearly twelve thousand feet above the earth, the first sight of the sun was obtained, and the view at that moment spread before the aeronauts was magnificent beyond description. A rapid descent, which shortly after took place, again brought them into the gloom of night, the bright morning beams not having illumined the lower regions of the air, and again did they rise and see the full glory of the rising luminary. Three times did they thus rise, and behold the sun, and twice did they, by descending into the mists and vapours which dimmed the scenery, lose sight of it ere it appeared fully above the horizon. Great was the pleasure of the voyagers when they perceived, as the mists cleared away, every indication of a well-peopled country and industrious population; and they made all possible preparations for descending, when, just as they were hastening their descent in a spot well suited for the purpose, the wind freshened, and before the grapnel could take a secure hold, the balloon was hurried towards a wooded declivity. To throw out a sufficiency of ballast to carry the machine over that danger was the only remedy, but the sand used as ballast was found to have been frozen during the night into a solid mass, consequently all that could be done was to throw a sack with all its contents out of the car, and fifty-six pounds of sand were instantly dismissed. The balloon immediately sprang up and cleared the declivity, and, to avoid passing by another spot suited to the descent, the valve was again opened, to allow a large quantity of the gas to escape. After various baffling occurrences, on reaching the edge of the wood, the valve was opened to its utmost extent, and the grapnel taking hold almost immediately after, the machine came to the ground in the valley of Elbern, two leagues from Weilburg, in the Duchy of Nassau, at half-past seven in the morning, after a voyage of eighteen hours' duration, in which time it had passed over a great part of five kingdoms, England, France, Belgium, Prussian Germany, and the Duchy of Nassau. The travellers were most hospitably entertained at Weilburg, and the machine was rechristened the Vauxhall Nassau Balloon.

AIR AND FIRE BALLOONS.

The air balloon should be made of taffeta or lutestring, and in shape similar to a pear; the best method of making it being by joining many slips together, from end to end: if you take a pear and divide it into twelve or fourteen slices, one of those pieces is the best pattern you can have for the shape of the slips of your balloon.

Having cut them out, each piece must be prepared with drying oil, which you may make yourself, by boiling in every pint of linseed oil two ounces of sugar of lead, and three ounces of litharge, for about half an hour. This composition is very drying, and you may then apply it to the slips of your balloon: after which, sew them together, and fell the seams. That the stitching may not have any interstices for the escape of the gas, you must place a piece of brown paper beneath each seam, and another piece above, and then pass a heated poker or

flat iron several times over it, by which means the oil will be softened, and the seams rendered perfectly air-tight. When this process is completed, you must give your balloon a coat of varnish. This may be prepared by boiling in a copper or iron gallon saucepan, over a slow charcoal fire, for about half or three-quarters of an hour, a pound of birdlime, and half a pint of the drying oil. When the birdlime has ceased to crackle, pour in two pints and a half more of the drying oil, and let the mixture boil an hour longer, often stirring it with an iron or wooden spoon. You must be cautious not to let the varnish boil over, which it is very apt to do when nearly ready, taking the saucepan from the fire, as the varnish swells, and replacing it when its bubbling subsides; and, for greater caution, it will be well to have some wet cloths at hand to clap over the vessel, in case the contents should happen to boil over and take fire. To ascertain whether your varnish is ready, rub some between two knives; if, on separating them, it forms threads, remove the vessel from the fire, and when nearly cool, add to it about as much of oil of turpentine as the quantity of the mixture within. The varnish must be lukewarm when applied, and the balloon stretched out, and it will be dry in twenty hours. It should be the aim of the aeronaut to make his miniature balloon as much like a real one as possible: he must make a net to the shape of the machine, so as to come down to about the middle of it, and from thence cords must depend for the purpose of sustaining a light hoop, which should hang a little below the balloon itself; from this hoop other strings must proceed to support the car, which may be made of any light material and elegantly painted.

When the balloon is finished, it may be filled with gas: for this intent put into a glass bottle, or jar, a pound of iron filings and two quarts of water; to which add gently, and by a little at a time, one pint of sulphuric acid. This done, stop the bottle or jar with a cork; then take a glass tube, introduce one end of it into the bottle, through the cork, and the other end into the neck of the balloon, and the gas resulting from the decomposition of the water will pass through the glass tube into the balloon. When this is full, withdraw the tube, and tie the neck of the balloon very tight. If let free, it will rise very pleasingly.

In making a fire balloon you may use India, Bank post, or tissue paper, and omit entirely the drying oil and varnish. If, after having joined and pasted the seams with good strong paste, you perceive any interstice or hole, paste over it a little piece of paper, and let it dry in the open air, or by the fire, but not too near it. A wire must be secured round the neck of the balloon, either by pasting or sewing it, and another put horizontally across it, to the middle of which a piece of sponge dipped in spirit of wine is to be attached. Half a gill of the spirit is sufficient to make the balloon rise. After you have dipped your sponge, set fire to what spirit remains in the cup, holding the neck of the balloon over it, but not so close as to endanger its safety. When you think it is sufficiently filled with heated air, set fire to the sponge, and the machine will briskly ascend, and keep afloat so long as the spirit continues burning.

Very small balloons may be made of goldbeaters' skin, by using gum-arabic to join the seams and any little fissures which may be in the material, filling them with gas from a jar or bottle, as before described, and tying the mouths of the little machines with a piece of cotton, to prevent the escape of the gas: small cars may be also attached to them, and when they are let off in a room, they will rise to the ceiling, and remain floating in the air for some time.

At the shops of philosophical instrument makers, in bazaars, and at toy-shops a very pretty balloon made of the maw of a turkey can be purchased: when filled with hydrogen gas, in the manner described for air-balloons, it will ascend beautifully, on account of its extreme lightness.

PARACHUTES,

Which are generally the first things a juvenile aeronaut perpetrates, may be made in two ways: the first and simplest is achieved by cutting a piece of tissue paper into a circular form, putting eight or twelve pieces of thread at regular distances and of equal lengths to it, drawing them all up evenly to a centre and knotting them together, and completing the apparatus by affixing a cork or a wisp of paper to the end of the strings: the second mode of parachute-making is more complex, and must be done on a principle similar to that we have described for constructing the air-balloon, but cutting the slips of silk so as to form, when united, the segment of a circle only; the strings must of course be added, and brought to a centre, and a pill-box-shaped car, painted and embellished as tastefully as the genius of the contriver will allow, suspended from the aforesaid centre.

BALLOON SIGNALS.

In the days of the Directory and of the consulate of Napoleon, balloons were much used for taking observations. Buonaparte intended to take some with him to Egypt, but the vessel in which the balloons and materials were stowed away was captured by Nelson's fleet, and the balloons were exhibited to the inhabitants of Cairo for their amusement, and were not employed (as was intended) to the disadvantage of the English.

The Americans have done little in ballooning. One was constructed on quite a different principle to those of the "Old World." It had forty-seven bags for the gas instead of one. The American *savants* proceeded to try their experiment very cautiously, first letting the balloon up alone, then a man in it, whilst fastened with ropes. At last a carpenter named Wilcox was bribed to ascend. He did so, but soon became frightened and began to cut the bags nearest to him. Wilcox cut five, and in consequence of ripping them open all on one side, the balloon turned over and came to the ground very fast, dislocating his wrist only, to the great surprise of the spectators, who fully expected that the carpenter was killed with the concussion.

The object of Napoleon's balloon was partly to examine the surrounding country, and also to communicate to distant parts by signals; and,

should war unhappily continue, it is quite possible to suppose that balloon corps may be attached to the various European armies, although the monstrous range of the Enfield and other rifles might probably make personal ascents for observation somewhat perilous.

One of the most interesting applications proposed for balloons was made in March, 1848, by Mr. J. Wallace, of Leith, to Sir F. Baring; viz., to make a survey of the icy regions with the help of a captive balloon, which was to have been sent to the greatest possible height the weight of the cord would permit, in order that the person seated in the car might be able, with the help of a telescope, to survey a larger range of country, with the hope of discovering the missing expedition of the unfortunate Sir John Franklin.

For many reasons this scheme with the captive balloon (*a là Napoléon*) was abandoned, and one substituted for it, which Mr. Shepherd has the credit of having first offered to the Admiralty. The arrangement consisted of a number of printed packets of oiled silk or paper, upon which directions were printed stating the latitude and longitude of the exploring ships, where they were going to, and the localities at which provisions had been left. These were attached at proper intervals to a long slow match made of rope dipped in nitre; and as the balloon travelled over the country, the match burnt gradually away, and when the fire reached the packets, they were detached, and would, by the action of the winds, be dispersed over a large space of ground.

About the same time Mr. Darby, the very eminent pyrotechnist of Lambeth, turned his attention to the same subject, and constructed some very ingenious signals, which were attached by string to a hollow fuse, and as this burnt away the string was detached. By the same means the "petard signals," or explosive shells, giving a report equal to a seven-pounder cannon directly they touched the ground, and dispersing hundreds of little notices in tinfoil,

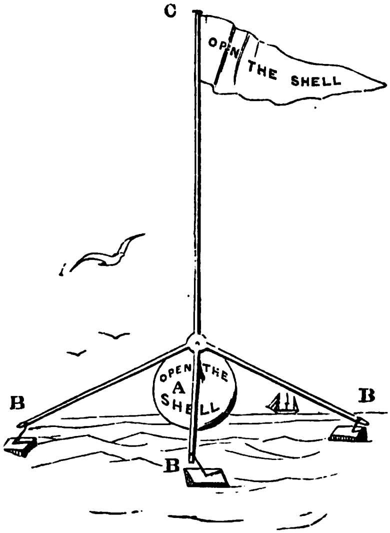

Fig. 96. Darby's land and water signal. A. The shell, made of gutta-percha, containing the message. B, B, B. Four pieces of stout cane with corks at the extremities. C. Top cane, with little bunting-flag.

were detached, and used with great success as a means of directing attention, by sound, to the little bills containing the desired information for the missing party of Sir J. Franklin. Mr. Darby also constructed a "bill distributor," attached to his hollow fuse, capable of delivering 100,000 bills or notices over a great space of country; likewise a "land and water signal," which remained erect whether dropped on the sea or *terra firma.* The whole of the signals were tried with great success, and three of the "land and water signals" were picked up after being detached from a balloon launched from Vauxhall. One was picked up at Harwich, another at Brighton, and a third near Croydon: the last was discovered by a poor man, who, fearful of something explosive, did not open it; but, calling in a gentleman who resided in the neighbourhood, the shell was cut open and a polite note discovered requesting the finder to state where the signal had fallen, and to address a letter to Mr. Darby, at Vauxhall Gardens.

Fig. 97. Flying Machine (*theoretical*).

ARITHMETIC.

THE science of ARITHMETIC is supposed to be coeval with the earliest inventions. According to Diogenes Laertius, the Egyptians may lay claim to the merit of being its discoverers, but other authors ascribe it to the Phœnicians. The Phœnician system was perfected by the Grecian astronomers, and transmitted by them to the Romans, who, however, invented a fresh one instead; but both systems merely combined the different divisions of numbers, and went no further. Counters, to assist in reckoning, are without doubt, as old as the science of Arithmetic itself, as we find that the Egyptians used stones for that purpose, and in calculating by their aid, placed them from left to right. The Greeks likewise employed stones, flat, rounded, and polished, and they sometimes signified a large number, and sometimes a small; when counting up, the Greeks ranged their counters the reverse way to that of the Egyptians, putting them from right to left.

The Romans denominated their counters *calculi,* and when luxury taught them to embellish even the smallest articles in use, they then made the counters of bone, and ivory, slightly convex, and likewise of porcelain covered with green or blue enamel, and ornamented with elegant devices. The Romans also used the *abacus* as an arithmetical assistant; this instrument consisted of a wooden frame divided into small bars, of which there were two compartments, each bar containing beads, which could be moved up and down. The mode of using it was to consider every bead either as a unit or a decimal, adding being performed by uniting, and subtracting by separation, as might be necessary. Besides the counters, and the primitive mode of finger-reckoning, the Romans had a plan of keeping accounts by three different methods, based upon imaginary money; and these methods, styled the *ærariarius, sestertiarius,* and *denariarius,* required a particular abacus or table for each.

From the accounts remaining of the Roman method of Arithmetic, their rules were perplexing and incongruous, and the science made but little advancement under their management.

Numeral characters seem to have preceded letters, and the figures we call *Roman characters,* are considered specimens of the earliest

attempts at a system of notation, a surmise founded on the simplicity of their forms, which are, in fact, only a combination of straight strokes drawn either perpendicularly, horizontally, or transversely; and indeed, the figures representing a hundred, and five hundred C, D, which are now circular, were originally composed of three straight lines combined thus, [.]. With these rude symbols, the Grecian philosophers performed their arithmetical calculations, and established a system to which Archimedes and other men of most transcendant abilities contributed. Two species of numerical characters seem to have existed from the first; the *decimal*, mentioned by Pliny, Quintilian, &c., which took its origin from the plan of finger counting, consisted of the numbers counted up to ten;—and the *duodecimal*, or numbers reckoned to twelve. The former was common with the Anglo-Saxons, and the latter with the northern nations, and from this last also we derive our little hundred, great hundred, dozens, and grosses.

Arithmetic was studied as a science by the Anglo-Saxons, for Aldhelm, Bishop of Sherborne, who flourished in the 7th century, wrote a tract *de Arithmetica*, and at a later period, Hugh, the Lincoln saint, lectured upon it at Oxford. The want of numerals better adapted for complicated accounts than the Roman, rendered summing a miserable task, and the use of counters indispensable, until the fourteenth century, when the characters known by the name of the Arabic numerals were introduced into Europe. The Arabs were not inventors of the system, but were indebted for it to the natives of India, though at what period they acquired it is extremely doubtful, neither can we determine whether the Indians themselves invented or received it from some other nation; yet from their own assertions, it would seem that the honour is due to them; for according to Alsephaide, a learned Arabian doctor, they boast of three different inventions, the composition of Pilpay's fables, the game of chess, and the nine digital characters. The forms of the ciphers were not fully settled till after the year 1531; and perhaps no characters were ever planned more adapted for the various uses to which they are applied than the Arabic numerals, though we doubt not that some few of our readers have frequently wished in their hearts that they never had been invented.

TO FIND THE DIFFERENCE BETWEEN TWO NUMBERS, THE GREATER OF WHICH IS UNKNOWN.

Take as many nines as there are figures in the smaller number, and subtract from them the amount of the number. Request some one to add the difference to the larger number, to take away the first figure of the total, and add it to the last one, and the sum then produced will be the difference between the two numbers.

For example:—John, who is 22, tells George who is some years older, that he can find out the difference in their ages; he therefore

deducts in his mind 22 from 99, and the difference, 77, he tells George to add to his own age; to take away the first figure from the sum so obtained, and to add it to the last figure; the last amount gained being the difference between their respective ages.

Thus, the difference between John's age and 99, is	77
To which George adding his age	35
produces a total of	112
From which if we take away the first figure 1, and add it to the last figure 2, the product is	13
Which if added to John's age	22
exactly gives that of George	35

THREE COUNTRYWOMEN AND EGGS.

Three countrywomen went to market with eggs: the first had 50 to dispose of, the second 30, and the third no more than 10. All three sold out at the same rate, and each made the same quantity of money of her eggs. How were they sold? Upon coming to market, they found that eggs were selling at seven a-penny, at which rate the first woman sold 49, and received seven-pence; the second sold 28, and of course received four-pence; and the third woman sold only a single penny worth, so that she had three eggs remaining, whilst her companions had but one and two respectively. In the course of the day the demand greatly increasing, she advanced her price to three-pence per egg, at which rate she sold the remainder of her stock, and received ninepence for it.

Her companions following her example, sold off theirs also at the same price, so that they each realized the sum of ten-pence.

1st woman for 49 eggs, received...	7
and for 1 egg	3
	10
2nd woman for 28 eggs...	4
and for 2 eggs	6
	10
3rd woman for 7 eggs	1
and for 3	9
	10

TO MAKE ANY NUMBER DIVISIBLE BY NINE, BY ADDING A FIGURE TO IT.

Suppose, for example, that the number named is 72,857, desire the person naming it to place the number 7 between any two figures of that sum, and it will be divisible by 9; for if any number is multiplied by nine, then the sum of the figures of the product, will either be nine, or else the number which is divisible by it.

THE DIGITAL NUMBERS ARRANGED SO AS TO GIVE THE SAME PRODUCT, WHETHER COUNTED HORIZONTALLY, DIAGONALLY, OR PERPENDICULARLY.

8	3	4
1	5	9
6	7	2

THE BASKET AND STONES.

If a hundred stones are placed in a straight line, a yard distant from each other, how many yards must a person walk, who undertakes to pick them up, one by one, and put them into a basket, placed also a yard from the first stone? It is clear that to pick up the first stone and put it into the basket, the person must walk two yards, one in going for the stone, and the other in returning with it; that for the second stone, he must walk four yards, and so on, increasing by two, as far as the hundredth, when he must, of necessity, walk two hundred yards: so that the sum total will be the product of two hundred and two, multiplied by fifty, or 10,100 yards, which amounts to more than five miles and a half.

A MAGIC SQUARE.

A magic square, is a square figure formed of a series of numbers in mathematical proportion, so arranged in parallel and equal ranks, as that the sums of each row, whether taken perpendicularly, horizontally, or diagonally, are exactly equal.

The several numbers which make any square number (for instance, 1, 2, 3, 4, 5, &c., to 25 inclusive, which compose the square number 25), being arranged one after the other in a square figure of 25 cells, each one in its cell, if you alter the order of these numbers, and put them in such a manner that the five numbers which fill a perpendicular rank of cells being added together, shall make the same number with the five numbers in any other rank, whether horizontal or vertical, or with the five in each of the two diagonal rows, then the square so formed is called a magic square, in opposition to the former arrangement, which is called a natural square.

A NATURAL SQUARE.

	A		G		B	
	1	2	3	4	5	
	6	7	8	9	10	
E	11	12	13	14	15	F
	16	17	18	19	20	
	21	22	23	24	25	
	C		H		D	

A MAGIC SQUARE.

A				B
11	24	7	20	3
4	12	25	8	16
17	5	13	21	9
10	18	1	14	22
23	6	19	2	15
C				D

Any five of the sums in the magic square, taken in a right line, will make 65. It will be observed, that the five numbers in the diagonals, A D and B C of the magical square, answer to the ranks E to F and G to H in the natural square, and that 13 is the centre number of both squares.

To form a magic square, first transpose the two ranks in the natural square to the diagonals of the magic square; then put the number 1 under the central number 13, and the number 2 in the next diagonal, downwards. The number 3 should be placed in the same diagonal line; but as there is no room in the square, you are to place it in that part it would occupy were another square placed under it. For the same reason, the number 4, by following the diagonal direction, falling out of the square, it is to be put into the part it would hold in another square ranged by the side of this. You next proceed to numbers 5 and 6, still descending, but as the square in which 6 should be put is already filled, you must then go back to the diagonal, and consequently place the 6 in the second place under the 5, so that there may remain an empty square between the two numbers. The same rule is to be observed whenever you find a square already filled.

You proceed in this manner to fill all the empty squares in the angle, where the 15 is put; and as there is no space for the 16 in the same diagonal, descending, you must place it in the part it would hold in another square, and continue the same plan till all the squares are filled. This method will serve for all sorts of arithmetical progressions composed of odd numbers; even numbers being too complicated to afford any amusement.

A PERSON HAVING AN EVEN NUMBER OF SHILLINGS IN ONE HAND, AND AN UNEVEN NUMBER IN THE OTHER, TO TELL IN WHICH HAND THE EVEN OR ODD NUMBER IS.

Request the person to multiply the number in his right hand by an odd figure, and the number in his left by an even one, and let you know whether, when the products are added together, they produce an odd or even sum. If odd, then the even number is in the left

hand, and if even, the even number is in the right. As for instance:

The number in the right hand being *odd*	7	In the left hand, *even*	18
Multiply it by	3	Multiply it by	2
Product	21	Product	36
Add the product of the left hand	36		
and the total is	57		
The number in the right hand being *even*	18	In the left hand, *odd*	7
Multiply it by	3	Multiply it by	2
Product	54	Product	14
Add the product of the left hand	14		
and the total is	68		

COUNTRYWOMAN AND EGGS.

A countrywoman carrying eggs to a garrison, where she had three guards to pass, sold to the first guard half the number she had, and half an egg more; to the second, the half of what remained, and half an egg besides; and to the third guard, she sold the half of the remainder, and half another egg. When she arrived at the market-place she had three dozen still to sell, how was this possible without breaking any of the eggs? It would seem at the first view that this is impossible, for how can half an egg be sold without breaking any of the eggs? The possibility of this seeming impossibility will be evident, when it is considered, that by taking the greater half of an odd number, we take the exact half + ½. When the countrywoman passed the first guard, she had 295 eggs; by selling to that guard 148, which is the half + ½, she had 147 remaining; to the second guard she disposed of 74, which is the major half of 147; and, of course, after selling 37 out of 73 to the last guard, she had still three dozen remaining.

TO TELL THE NUMBER THOUGHT OF BY A PERSON.

Request a person to think of a number, and when he has done so, to triple it, and to take the exact half of the triple, if it be even, or the greater half if it be odd. Next desire him to triple that half, and ask him how many times it will contain nine, for the number thought of will be the double of the number of nines, and one more, if it be odd. Thus suppose that 5 is the number thought of, its triple is 15, which cannot be divided by two, without a remainder.

The greater half of 15 is 8, and if this is multiplied by 3, we shall have 24, which contains two nines; the number thought of will therefore be twice the number of nines, with one added, as beforementioned, for an uneven number, or 4 + 1, that is 5.

ANOTHER METHOD.

When the person has thought of a number, tell him to double it, then to add four to it, to multiply the whole by five, and to the product add twelve, and afterwards multiply the total by ten. From the sum thus produced, bid him deduct 320, and inform you what is the remainder, which, if you take away the two last figures from it, will give you the number he thought of. Thus:

Suppose the number selected is	7
The double of that is	14
Which with the addition of 4 is	18
And that multiplied by 5 is	90
To which 12 added produces	102
Which multiplied by 10 is	1020
From which, by deducting 320, there remains ...	700
And which, by taking away the two ciphers, is reduced to the number thought of	7

TO TELL TWO OR MORE NUMBERS WHICH A PERSON HAS THOUGHT OF.

If either of the numbers thought of do not exceed nine, they may be found as follows:—Make the person add 1 to the double of the first number thought of, and then request him to multiply the whole by 5, and then add to the product the second number. Should there be a third number, make him double the first sum, and add 1 to it; request him then to multiply the whole by 5, and to add the third number to it. If there is a fourth number, you, of course, proceed in the same way, requesting him to double the preceding sum; to add 1 to it, then to multiply it by 5, and thereto add the fourth number, and so on. You must next ask the number arising from the addition of the last number thought of, and if there were two numbers, subtract 5 from it; if three, 55; and if four, 555, and so on; for the remainder will always be composed of figures, of which the first on the left hand is the first number thought of, the next the second, and so on of the rest. Suppose, for instance, the numbers thought of are 3, 4, 6, by adding 1 to 6, which is the double of the first number, we have 7, which being multiplied by 5, gives 35; if 4, the second number thought of is then added, we shall have 39. which doubled gives 78, and if we add one, and multiply 79 by 5, the result will be 395. Finally, if we add 6, the third number thought of, the sum total will be 401, and if we deduct 55 from it, we shall have for the remainder 346: the figures of which, 3, 4, 6, are the three numbers thought of in their correct order.

A PERSON STRIKING A FIGURE OUT OF THE SUM OF TWO GIVEN NUMBERS, TO TELL WHAT THAT FIGURE WAS.

Peremptorily command such numbers only as are divisible by 9, as, for instance, 36, 63, 117, 126, 162, &c. Then allow a person to choose any two of these numbers; and after adding them together, in his mind, to strike out from the total any one of the figures he pleases. When he has done this, desire him to tell you the sum of the figures, and it follows that the number you are obliged to add to this amount, in order to make it 9 or 18, is the one he struck out. For example, he chooses the numbers 126 and 252, whose aggregate sum is 378. Then if he strikes out the 7 from this amount, the remaining figures, 3 and 8, will make 11, to which must be added 7 to make 18; but if he strikes out the 3, the sum of the remaining figures, 7 and 8, will be 15, add to which 3, to make 18; and so, in like manner, for the 8.

THE HORSE-DEALER'S BARGAIN.

A horse-dealer, wishing to dispose of a horse at as high a price as he could, induced a gentleman who admired it to become the purchaser, by offering to let him have the animal for the value of the twenty-fourth nail in his shoes, reckoning one farthing for the first nail, two for the second, four for the third, and so on, to the twenty-fourth. The gentleman, thinking it a bargain, gladly accepted the offer; the value of the horse was therefore necessarily great. By calculation, the twenty-fourth term of the progression, 1, 2, 4, 8, &c., will be found to be 8,388,608, equal to the number of farthings the purchaser gave for the horse; the price consequently amounted to £8738 2s. 8d.

TO FIND THE LEAST NUMBER OF WEIGHTS WHICH WILL WEIGH ANY INTERMEDIATE WEIGHT, FROM ONE POUND TO FORTY, EXCLUSIVE OF FRACTIONS.

This problem may be solved through the means of the geometrical progression, 1, 3, 9, 27, &c., the peculiar property of which is, that the last number is twice the sum of all the rest, and one more; so that, the number of pounds being 40, which is likewise the amount of 1, 3, 9, 27, these four weights will answer the purpose. For example, if it be necessary to weigh eleven pounds by these weights, the three and the nine pound weights must be put into the one scale, and the one pound weight into the other, therefore, any substance put into this last scale, with the one pound weight, and it remains in equipoise with the other scale, it must consequently weigh eleven pounds. Again, if a weight of fourteen pounds is required, the one, the three, and the nine pounds weights should be put into one of the scales, and the twenty-seven pounds weight into the other, which will then outweigh the first scale by the exact number needed. Any other weights may be made by similar combinations.

THE FIGURES, UP TO 100, ARRANGED SO AS TO MAKE 505 IN EACH COLUMN, WHEN COUNTED IN TEN COLUMNS PERPENDICULARLY, AND THE SAME WHEN COUNTED IN TEN FILES HORIZONTALLY.

10	92	93	7	5	96	4	98	99	1	Each of these files, when added up, makes 505.
11	19	18	84	85	86	87	13	12	90	
71	29	28	77	76	75	24	23	22	80	
70	62	63	37	36	35	34	68	69	31	
41	52	53	44	46	45	47	58	59	60	
51	42	43	54	56	55	57	48	49	50	
40	32	33	67	65	66	64	38	39	61	
30	79	78	27	26	25	74	73	72	21	
81	89	88	14	15	16	17	83	82	20	
100	9	8	94	95	6	97	3	2	91	

Each of these ten columns, when added up, makes 505.

TO FIND HOW MANY SQUARE YARDS IT WOULD REQUIRE TO CONTAIN IN WRITING ALL THE CHANGES OF THE ALPHABET, EACH LETTER WRITTEN SO SMALL AS NOT TO OCCUPY MORE THAN THE HUNDREDTH PART OF A SQUARE INCH.

By multiplying the numbers from 1 to 24, continually into each other, thus—

$$\begin{array}{r} 1 \\ 2 \\ \hline 2 \\ 3 \\ \hline 6 \\ 4 \\ \hline 24 \end{array}$$

the changes of the twenty-four letters will be found to be,—

62,044,840,175,323,943,936,000.

Now, as there are 1296 inches in a square yard, if we multiply that number by 100, we shall obtain 129,600, which is the number of letters each square yard will contain; if we afterwards divide the above row of figures,—the number of changes,—by the 129,600, the quotient, which will be 478,741,050,720,092,160, is the number of yards required to contain the before stated number of changes. But, as all the twenty-four letters are contained in every permutation, the space must necessarily be twenty-four times as large, viz.

11,849,785,210,282,211,840.

As the surface of the whole earth contains but 617,197,435,008,000, square yards, it would consequently require, to make a space of suffi-

cient dimensions to contain all the changes of which the alphabet is susceptible, a surface 18,620 times larger than that of the globe.

THE NUMBER FORTY-FIVE.

How can the number 45 be divided into four such parts that if you add two to the first part, subtract two from the second part, multiply the third part by two, and divide the fourth part by two, the total of the addition, the remainder of the subtraction, the product of the multiplication, and the quotient of the division, are all equal? The four parts are as follows:

The first is 8, to which 2 being added, makes ...	10
The second is 12, from which 2 being subtracted, leaves	10
The third is 5, which being multiplied by 2 produces	10
The fourth is 20, which, divided by 2, the quotient is	10

PROFIT AND LOSS.

A man purchased ninety-six apples at the rate of three a penny, and likewise the same number at two a penny; he sold them again at five for two pence, did he gain or lose? He lost, for as the ninety-six apples at three a penny cost him 2s. 8d. and the ninety-six at two a penny, 4s., the sum he laid out was 6s. 8d. for the one hundred and ninety-two apples. Now, after he sold thirty-eight two-pennyworths, for which he received 6s. 4d., he had but two apples remaining, and therefore he lost a fraction above 3½d.

THE PHILOSOPHER'S PUPILS.

Tell me, illustrious Pythagoras, how many pupils receive instruction from thy lips? Nay, said the philosopher, compute the number thyself; one half of my pupils study mathematics, one fourth natural philosophy, one seventh observe silence, and besides those I have three female pupils. The question is to find out a number, the one-half, one-fourth, and one-seventh of which, + 3, shall be equal to that number. The number required is 28.

THE COMPANY OF FOUR MERCHANTS.

Four partners engage to trade in company—Smith's stock is £150; Brown's stock is £320; Collins's stock is £350, and Jenkins's stock is £500; with their money they buy indigo, and gain £730. How much belongs to each, if the profit be divided in proportion to their respective stocks.

	£		£	*s.*	*d.*
Smith's stock	150	1320 : 150 :: 730 :	82	19	1*
Brown's ,,	320	1320 : 320 :: 730 :	176	19	4
Collins's ,,	350	1320 : 350 :: 730 :	193	11	2
Jenkins's ,,	500	1320 : 500 :: 730 :	276	10	3
Whole stock...	1320		£730		

* Fractions omitted.

Smith....................	82	19	1
Brown	176	19	4
Collins	193	11	2
Jenkins..................	276	10	3
	£730		

ROAD MAKING.

If 100 men make three miles of road in twenty-seven days, in how many days will 150 men make five miles?

Men 150 : 100 :: 27 days.
Miles 3 5

450 500
27

450)13500(30 days.

THE TWO TRAVELLERS.

Two poor boys, Tom and Ned, walk between London and Wolverhampton; Tom leaves the latter at eight o'clock in the morning, and walks at the rate of three miles an hour without intermission, and Ned sets out from London at four o'clock the same evening, and walks for Wolverhampton at the rate of four miles an hour constantly. Now supposing the distance between the two places to be 130 miles, and supposing the boys capable of continuing their journeys, whereabouts on the road will they meet?

Answer—$69\frac{3}{7}$ miles from Wolverhampton.

TO DISCOVER THE BREADTH OF A RIVER BY MEANS OF THE BRIM OF A HAT, OR PEAK OF A CAP.

The person seeking to ascertain this fact must place himself at the edge of one bank of the river and lower the brim of his hat, or peak of his cap, till he finds the edge just cuts the other bank; then after placing the hand under the chin, he must turn round steadily till he faces some level ground on his own side of the river, and observe when the edge of the peak again meets the ground, the measure of this distance will be very nearly the breadth of the river.

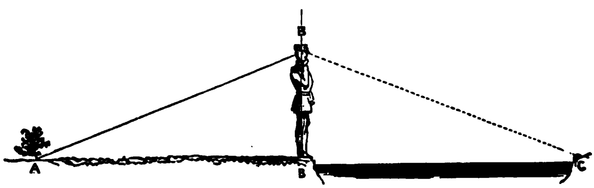

Fig. 98. Showing that the angles A B B and C B B are equal.

How many dinners would be necessary for a club of seven persons who had agreed to dine with each other as long as they could be differently arranged when they sat down to table?

The number of dinners is 5040, and thirteen years and more than nine months would be the space of time in which the club would eat the dinners.

How much mahogany would be required to produce sixty-four 3-inch cubes?

The quantity is a 12-inch cube.

According to Vitruvius, Hiero's crown weighed 20lbs. and lost $1\frac{1}{4}$lb. (nearly) in water.

Suppose it consisted of gold and silver only, and that 19·64lbs. gold lost 1lb. in water, and that 10·5lbs. of silver lose 1lb.: find the actual quantity of gold in King Hiero's crown and also the weight of the silver with which it was adulterated.

Answer x = the lbs. of gold in crown.
$20-x$ = the lb. of silver in crown.

Hence we immediately have—

$$\frac{x}{19.64} \times \frac{20-x}{10.5} = 1\tfrac{1}{4}\text{lbs.}$$

And solving this equation, we have—

Answer—$x = 14.77$ lbs. of gold in crown
and $20-x = 5.22$ lbs. of silver in do.